AD-A049 882 IIT RESEARCH INST ANNAPOLIS MD F/G 1/5

INTERFERENCE ANALYSIS BETWEEN TRSB MICROWAVE LANDING SYSTEM AND--ETC(U)

FEB 76 V NANDA F19628-76-C-0017

UNCLASSIFIED FAA-RD-77-110 NL

| OF |

AD
A049 882

END

DATE
FILMED
3-78
DDC

12

FAA-RD-77-110

INTERFERENCE ANALYSIS BETWEEN TRSB MICROWAVE LANDING SYSTEM AND ADJACENT C-BAND RADARS

IIT Research Institute
Under Contract to
DEPARTMENT OF DEFENSE
Electromagnetic Compatibility Analysis Center
Annapolis, Maryland 21402

February 1976

FINAL REPORT

PUBLISHED JAN. 1978

Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, DC 20591

FAA-RD-77-110

(18) FAA-RD, ECAC

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-RD-77-110, (19) PR-76-004		(11)

4. Title and Subtitle	5. Report Date
(6) INTERFERENCE ANALYSIS BETWEEN TRSB MICROWAVE LANDING SYSTEM AND ADJACENT C-BAND RADARS.	February 1976
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
(10) VED/NANDA of IIT Research Institute	ECAC-PR-76-004

9. Performing Organization Name and Address	10. Work Unit No.
DoD Electromagnetic Compatibility Analysis Center North Severn Annapolis, Maryland 21402	(15) F19628-76-C-0012
	11. Contract or Grant No. DOT-FA70WAI-175

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation Federal Aviation Administration Systems Research and Development Service Washington, DC 20591 (16) 649E (12) 65p.	(9) Final Report,
	14. Sponsoring Agency Code ARD-60 65704F

15. Supplementary Notes

Performed for the Spectrum Management Staff, ATC Spectrum Engineering Branch, FAA.

16. Abstract

The Electromagnetic Compatibility between the Time Reference Scanning Beam (TRSB) Microwave Landing System (MLS) and adjacent C-band radar systems is investigated. Distance constraints required for compatible operation between these systems are established for the three proposed MLS plans of frequency assignment. An addendum to this report contains the data pertaining to those radars with classified characteristics.

NOTE: This report considers the TRSB MLS design as it was at the time the study was done. Since that time, a number of design changes have been made. These changes are not addressed in the report.

17. Key Words	18. Distribution Statement
C-BAND RADARS MICROWAVE LANDING SYSTEM	Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	66	

Form DOT F 1700.7 (8-69)

175 300 LB

FAA-RD-77-110

ENGLISH/METRIC CONVERSION FACTORS

LENGTH

To / From	Cm	m	Km	in	ft	s mi	n mi
Cm	1	0.1	1×10^{-5}	0.3937	0.0328	6.21×10^{-6}	5.39×10^{-6}
m	100	1	0.001	39.37	3.281	0.0006	0.0005
Km	100,000	1000	1	39370	3281	0.6214	0.5395
in	2.540	0.0254	2.54×10^{-5}	1	0.0833	1.58×10^{-5}	1.37×10^{-5}
ft	30.48	0.3048	3.05×10^{-4}	12	1	1.89×10^{-4}	1.64×10^{-4}
S mi	160,900	1609	1.609	63360	5280	1	0.8688
n mi	185,200	1852	1.852	72930	6076	1.151	1

AREA

To / From	Cm^2	M^2	Km^2	in^2	ft^2	S mi^2	n mi^2
Cm^2	1	0.0001	1×10^{-10}	0.1550	0.0011	3.86×10^{-11}	5.11×10^{-11}
m^2	10,000	1	1×10^{-6}	1550	10.76	3.86×10^{-7}	5.11×10^{-7}
Km^2	1×10^{10}	1×10^{6}	1	1.55×10^{9}	1.08×10^{7}	0.3861	0.2914
in^2	6.452	0.0006	6.45×10^{-10}	1	0.0069	2.49×10^{-10}	1.88×10^{-10}
ft^2	929.0	0.0929	9.29×10^{-8}	144	1	3.59×10^{-8}	2.71×10^{-8}
S mi^2	2.59×10^{10}	2.59×10^{6}	2.590	4.01×10^{9}	2.79×10^{7}	1	0.7548
n mi^2	3.43×10^{10}	3.43×10^{6}	3.432	5.31×10^{9}	3.70×10^{7}	1.325	1

VOLUME

To / From	Cm^3	Liter	m^3	in^3	ft^3	yd^3	fl oz	fl pt	fl qt	gal
Cm^2	1	0.001	1×10^{-6}	0.0610	3.53×10^{-5}	1.31×10^{-6}	0.0338	0.0021	0.0010	0.0002
liter	1000	1	0.001	61.02	0.0353	0.0013	33.81	2.113	1.057	0.2642
m^2	1×10^{6}	1000	1	61,000	35.31	1.308	33,800	2113	1057	264.2
in^3	16.39	0.0163	1.64×10^{-5}	1	0,0006	2.14×10^{-5}	0.5541	0.0346	2113	0.0043
ft^3	28,300	28.32	0.0283	1728	1	0.0370	957.5	59.84	0.0173	7.481
yd^3	765,000	764.5	0.7646	46700	27	1	25900	1616	807.9	202.0
fl oz	29.57	0.2957	2.96×10^{-5}	1.805	0.0010	3.87×10^{-5}	1	0.0625	0.0312	0.0078
fl pt	473.2	0.4732	0.0005	28.88	0.0167	0.0006	16	1	0.5000	0.1250
fl qt	948.4	0.9463	0.0009	57.75	0.0334	0.0012	32	2	1	0.2500
gal	3785	3.785	0.0038	231.0	0.1337	0.0050	128	8	4	1

MASS

To / From	g	Kg	oz	lb	ton
g	1	0.001	0.0353	0.0022	1.10×10^{-6}
Kg	1000	1	35.27	2.205	0.0011
oz	28.35	0.0283	1	0.0625	3.12×10^{5}
lb	453.6	0.4536	16	1	0.0005
ton	907,000	907.2	32,000	2000	1

TEMPERATURE

^{o}F = 5/9 (^{o}C - 32)

^{o}C = 9/5 (^{o}F) + 32

FAA-RD-77-110

FEDERAL AVIATION ADMINISTRATION
SYSTEMS RESEARCH AND DEVELOPMENT SERVICE
SPECTRUM MANAGEMENT STAFF

STATEMENT OF MISSION

The mission of the Spectrum Management Staff is to assist the Department of State, Office of Telecommunications Policy, and the Federal Communications Commission in assuring the FAA's and the nation's aviation interests with sufficient protected electromagnetic telecommunications resources throughout the world to provide for the safe conduct of aeronautical flight by fostering effective and efficient use of a natural resource--the electromagnetic radio-frequency spectrum.

This objective is achieved through the following services:

- Planning and defending the acquisition and retention of sufficient radio-frequency spectrum to support the aeronautical interests of the nation, at home and abroad, and spectrum standardization for the world's aviation community.

- Providing research, analysis, engineering, and evaluation in the development of spectrum related policy, planning, standards, criteria, measurement equipment, and measurement techniques.

- Conducting electromagnetic compatibility analyses to determine intra/inter-system viability and design parameters, to assure certification of adequate spectrum to support system operational use and projected growth patterns, to defend the aeronautical services spectrum from encroachment by others, and to provide for the efficient use of the aeronautical spectrum.

- Developing automated frequency-selection computer programs/routines to provide frequency planning, frequency assignment, and spectrum analysis capabilities in the spectrum supporting the National Airspace System.

- Providing spectrum management consultation, assistance, and guidance to all aviation interests, users, and providers of equipment and services, both national and international.

PREFACE

The Electromagnetic Compatibility Analysis Center (ECAC) is a Department of Defense facility, established to provide advice and assistance on electromagnetic compatibility matters to the Secretary of Defense, the Joint Chiefs of Staff, the military departments and other DoD components. The Center, located at North Severn, Annapolis, Maryland 21402, is under executive control of the Assistant Secretary of Defense for Communication, Command, Control, and Intelligence and the Chairman, Joint Chiefs of Staff, or their designees, who jointly provide policy guidance, assign projects, and establish priorities. ECAC functions under the direction of the Secretary of the Air Force and the management and technical direction of the Center are provided by military and civil service personnel. The technical operations function is provided through an Air Force sponsored contract with the IIT Research Institute (IITRI).

This report was prepared for the Systems Research and Development Service of the Federal Aviation Administration in accordance with Interagency Agreement DOT-FA70WAI-175, as part of AF Project 649E under Contract F-19628-76-C-0017, by the staff of the IIT Research Institute at the Department of Defense Electromagnetic Compatibility Analysis Center.

To the extent possible, all abbreviations and symbols used in this report are taken from American Standard *Y10.19 (1967) "Units Used in* Electrical Science and Electrical Engineering" issued by the USA Standards Institute.

Reviewed by:

Ved P. Nanda

VED NANDA
Project Engineer, IITRI

J. M. DETERDING
Director of Contractor Operations

Approved by:

Thomas A. Anderson

THOMAS A. ANDERSON
Colonel, USAF
Director

M. A. Skeath

M. A. SKEATH
Special Projects
Deputy Director

EXECUTIVE SUMMARY

The Federal Aviation Administration (FAA) has developed a Microwave Landing System (MLS) concept which will be proposed to the International Civil Aviation Organization (ICAO) in the near future. The FAA is concerned about the mutual interference potential between MLS and adjacent band radar systems operating in the frequency range 5.25 to 5.8 GHz. Therefore, the FAA asked the DoD Electromagnetic Compatibility Analysis Center (ECAC) to investigate these interactions as a function of three proposed MLS frequency assignment plans. The EMC of MLS with other equipment on board the aircraft including adjacent band radar is covered in a separate report.[1]

The MLS and radar equipments to be considered in the analysis were identified and their interference criteria and thresholds established. The interference analysis was based on generating the frequency-distance curves for each interacting equipment pair with interference threshold as a parameter. The required distance constraints to preclude interference between MLS and radar systems for each of the three MLS frequency assignment options were derived from this data.

With one exception the separation constraints between TRSB MLS and radars in the 5.25 to 5.8 GHz band are not overly restrictive. The exception is the main beam to main beam interaction between airborne C-band radars and the ground, C-band, MLS Distance Measuring Equipment (DME) transponder which is likely to occur during the aircraft's final approach. The result of this interaction is based upon the expected level of the interfering signal above threshold. The degradation effect of these signals has not been determined. The implementation of an L-band DME, which now appears probable, will remove this potential problem.

The separation-distance requirements for frequency assignment options 1 and 6 are the same for the majority of the interactions between MLS and radar equipments. One major exception is the case of height-finding radars wherein option 1 has some advantages over option 6.

[1]Gawthrop, P. E., "MLS Intra-Aircraft Analysis," ECAC-PR-76-006, ECAC, Annapolis, MD, 1975.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

TABLE OF CONTENTS (Cont'd)

LIST OF ILLUSTRATIONS (Cont'd)

LIST OF TABLES

TABLE OF CONTENTS (Cont'd)

LIST OF TABLES (Cont'd)

LIST OF APPENDIXES

GLOSSARY OF SYMBOLS AND ABBREVIATIONS

AEROSAT	Aeronautical Satellite System
dB	decibel
dBi	dB above isotropic
dBm	dB above a milliwatt
DoD	Department of Defense
DME	distance measuring equipment
D_U	duty cycle
ECAC	Electromagnetic Compatibility Analysis Center
ESL	earth surface dependent loss
FAA	Federal Aviation Administration
F/D	frequency-distance
FSL	free space propagation loss
G_R	main beam gain of receiver
G_T	main beam gain of transmitter
ICAO	International Civil Aviation Organization
IR_SR	interference to receiver sensitivity ratio
K	coupling isolation
kHz	kilohertz
L_{PS}	path loss
MB	main beam
MLS	microwave landing system
MHz	megahertz
OFR	off-frequency rejection
OTR	on tune rejection
P_T	peak power output
R_S	receiver sensitivity
RX	receiver
SIR	signal to interference ratio
SL	sidelobe
TRSB	time reference scanning beam
TX	transmitter

SECTION 1

INTRODUCTION

BACKGROUND

The Federal Aviation Administration (FAA) has developed a Microwave Landing System (MLS) concept that will be proposed to the International Civil Aviation Organization (ICAO) in the near future. This system would provide precision-approach-and-landing guidance at civilian and military terminals for all classes of aircraft and various environments. The system will operate at "C" band in the 5.0-5.25 GHz frequency range. The MLS frequency range is divided into sub-bands for transmitting angle, ground-to-air distance and air-to-ground distance information. Initially the FAA tasked the DoD Electromagnetic Compatibility Analysis Center (ECAC) to evaluate and compare three MLS frequency plans (designated option 1, option 6, and translated option 6) in terms of the interference potential of the MLS with the Aeronautical Satellite System (AEROSAT) and Radio Astronomy systems. These interactions have been investigated and are covered in separate reports.[2,3] The FAA is presently concerned about the potential for mutual interference between the MLS and radar systems operating in the adjacent frequency range, 5.25 to 5.8 GHz. Because of this concern, the FAA tasked ECAC through Interagency Agreement DOT-FA70WAI-175, Task Assignment No. 29, to determine the mutual interference potential between MLS equipments and radar systems in the 5.25 to 5.8 GHz band. Interactions between systems collocated aboard the same aircraft are covered in a separate report (Reference 1).

OBJECTIVE

The objective of this analysis was to determine the potential for mutual interference between the MLS equipment and adjacent band radar systems for the three MLS frequency plans proposed by FAA, and to develop the distance constraints that will result in compatible operation of the systems for the cases with high interference potential.

[2]Wasson, L. A. and Frazier, R. A., *AEROSAT Earth Terminal Siting Constraints required for Compatible Operation with the MLS at NAFEC*, FAA-RD-77-7-LR, ECAC-CR-75-085, ECAC, Annapolis, MD, June 1975.

[3]Rocca, R. P., *Potential Interference to 6 cm CONUS Radio*, FAA-RD-77-111 ECAC-PR-75-002, ECAC, Annapolis, MD, 1975.

APPROACH

The 5.25-5.8 GHz frequency band is allocated to radar systems that perform weather/meteorological, height finding, and surveillance functions. Because the MLS and radar bands adjoin, the potential for mutual interference exists when an MLS transmitter illuminates a radar receiver or when a radar transmitter illuminates an MLS receiver. The mutual interference potential was determined from frequency-distance (F/D) plots obtained via the steps listed below:

1. The environmental equipments were identified from ECAC files. System parameters and the necessary characteristics of each of the MLS/Radar equipments were obtained from various sources.
2. Off-frequency rejection (OFR) curves were generated for the interacting transmitters and receivers.
3. The coupling isolation required between each of the interfering transmitter and the victim receiver pair was calculated for several values of interference threshold.
4. F/D curves were generated based on the data of steps (2) and (3).

Data tables were developed which show the minimum distance separations required to preclude interference between each MLS equipment and each radar system using the F/D curves, interference threshold values and the three frequency assignment plans.

SECTION 2

CHARACTERISTICS OF INTERFERING SYSTEMS AND ANALYSIS

INTRODUCTION

The microwave landing system is comprised of three airborne and three ground based equipments. Sixteen adjacent band radar systems were identified. This situation suggests that a large matrix of interactions between the MLS and the radar equipments needs investigation. However, a case by case investigation is not necessary because a close examination of the characteristics of the radar systems and their appropriate classifications leads to a limited number of interactions of interest. The selection of representative radar systems for this investigation was based upon the study of the equipment parameters which are described below.

Adjacent Band Systems

The adjacent band (5.25 to 5.8 GHz) systems capable of interacting with MLS can be divided into four broad categories. This classification was derived from the Nominal Characteristics File:

1. Meteorological/Weather Radars; typical models in this category include the AVQ-10, AVQ-30, AN/TPS-81, AN/FPS-77, AN/FPS-106.
2. Mobile-Transportable Height-Finding Radars; typical models in this category include the AN/TPS-37, AN/TPS-40A, and the AN/MPS-16.
3. Ship and Shore Search Radars; typical models in this category include the AN/SPS-10F, AN/SPS-5, AN/SPS-21, and the AN/SPS-4.
4. Classified Government Radio-Location Systems; these systems are considered in a separate, classified Appendix.

To investigate the interference potential between radars and the MLS, four representative radars (AN/FPS-77, AN/TPS-40A, AN/SPS-10F, AVQ-10) are selected. The pertinent characteristics of these radars are given in TABLE 1. The sources of this data are the published characteristics data and spectrum signature reports. The selection of these representative radars has been based on the following considerations:

1. A radar system which represents the typical parameters of the adjacent band radars. For example, the AN/FPS-77 radar has typical emission spectra and receiver selectivity, etc.

TABLE 1

CHARACTERISTICS OF REPRESENTATIVE ADJACENT BAND RADAR SYSTEMS

	Equipments			
Characteristics	AN/FPS-77	AN/TPS-40A	AN/SPS-10F	AVQ-10
Function/Type	Meteorological/ Weather (Land Based)	Height Finding (Transportable)	Ship & Shore Search	Navigational/ Weather (Airborne)
Frequency (GHz)	5.45 to 5.65	5.25 to 5.31	5.45 to 5.82	5.38 to 5.42
Peak Power Output (dBm)	85.5	90	84.5	78
Antenna Gain Main Beam (dBi)	36	43	30	28
Beamwidth 3-dB (Degrees) Azimuth	1.6	2.3	1.5	4
Elevation (Degrees)	1.4	0.5	16	4
Pulse Width (μsec)	2	2.5	0.25	2
Pulse PRF (P/sec)	186 to 324	300 to 364	610 to 625	400
Pulse Rise Time (μsec)	.08	0.21	0.024	0.07
Pulse Fall Time (μsec)	0.6	0.42	0.09	0.07
Receiver Sensitivity (dBm)	-109	-109	-95	-100

2. A radar system whose operating frequency may be adjusted closest to the MLS frequency channels. For example, the AN/TPS-40A radar may tune to a frequency of 5.25 GHz.

3. A radar system that has the widest bandwidth of transmitter emission spectrum and receiver selectivity. For example, the AN/SPS-10F radar has a 4000 kHz 3 dB emission spectrum bandwidth and a 5000 kHz receiver selectivity bandwidth.

4. A radar system which is airborne (e.g., AVQ-10).

5. A radar system that requires a high value of coupling isolation to the victim receiver. For example, a radar with high transmitter power and high antenna gain was chosen from each category.

The emission spectra and selectivity curves for these representative radars are given in Figures 1 to 4 and 5 to 8 respectively. The selectivity and spurious emissions are the measured data from spectrum signature reports. Although the emission spectra are obtained from the spectrum signature reports, the slopes and breakpoints of the plotted curves are based on the Mason-Zimmerman plots.

MICROWAVE LANDING SYSTEM

The MLS, which operates within the 5.0 to 5.25 GHz frequency band, functions as an aircraft non-visual approach and landing system. It is an air-derived system in which the position information is directly measured in the aircraft. The ground equipment consists of an angle-guidance transmitter and a distance-measuring-equipment (DME) transponder. The aircraft equipment consists of an angle measuring reciever and DME interrogator. Angle information is provided by a time reference system technique which sweeps a narrow bandwith signal across the desired coverage volume using a narrow-beamwidth antenna pattern. The DME utilizes pulse-modulation techniques to select a particular ground station and obtain the distance information.

In the DME operation the aircraft DME transmitter transmits a pulse pair, which corresponds to the particular ground DME station selected. When the aircraft is within the nominal service volume, i.e., at or below 20,000 ft. altitude and within 20 nautical miles of the airport, the ground DME transponder will receive this signal, process it and transmit a pulse code reply back to the aircraft. If the processing time is allowed for, the only other delay encountered by the signal is the propagation time; one half of which is converted directly into the slant range by the DME airborne interrogator

There are three frequency assignment plans under consideration for the operation of the MLS. These plans, designated option 1, option 6 and translated option 6, are presented in Figure 9. Option

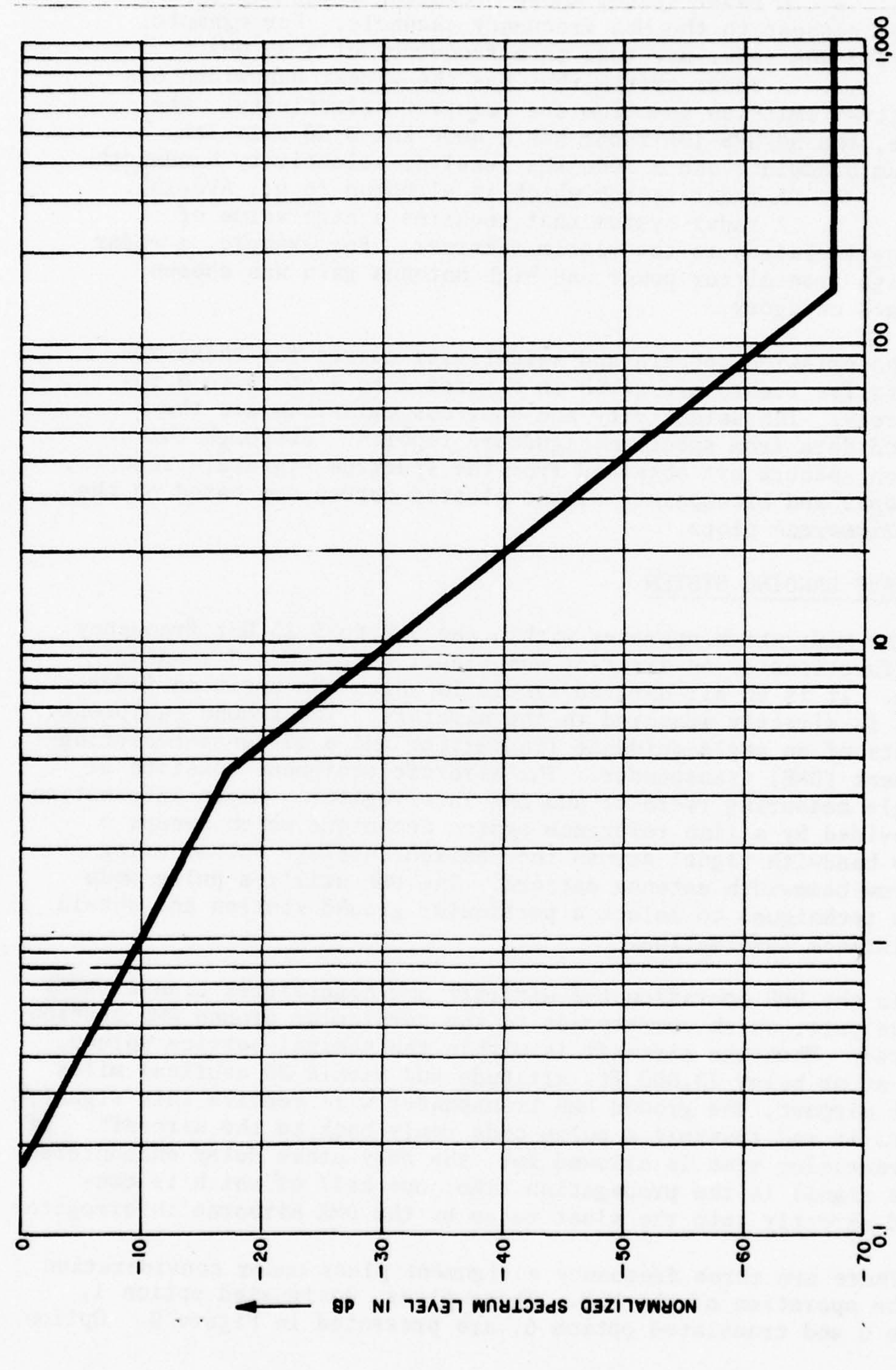

Figure 1. Emission spectrum: AN/FPS-77 transmitter.

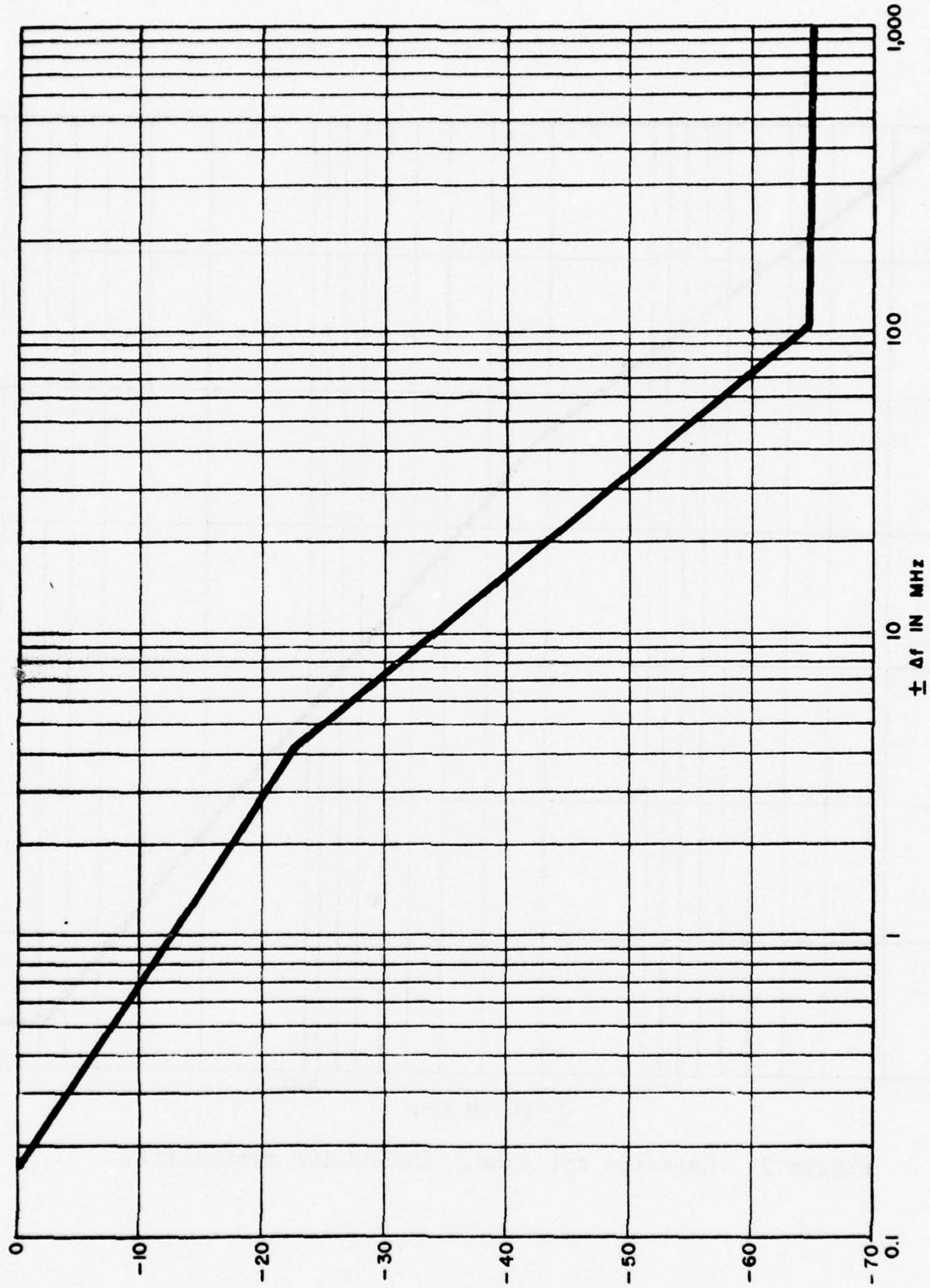

Figure 2. Emission spectrum: AN/TPS-40A transmitter.

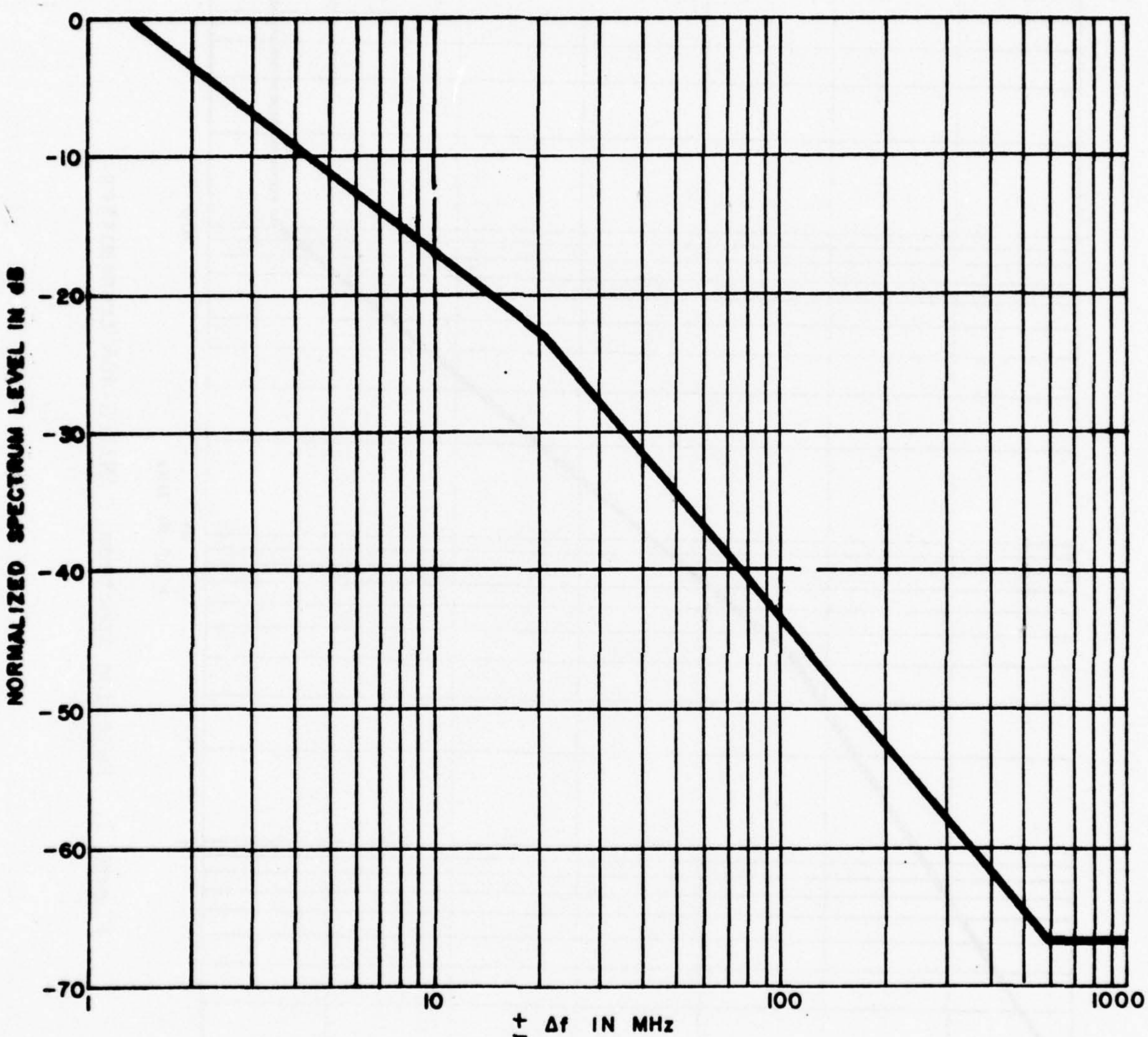

Figure 3. Emission spectrum: AN/SPS-10F transmitter.

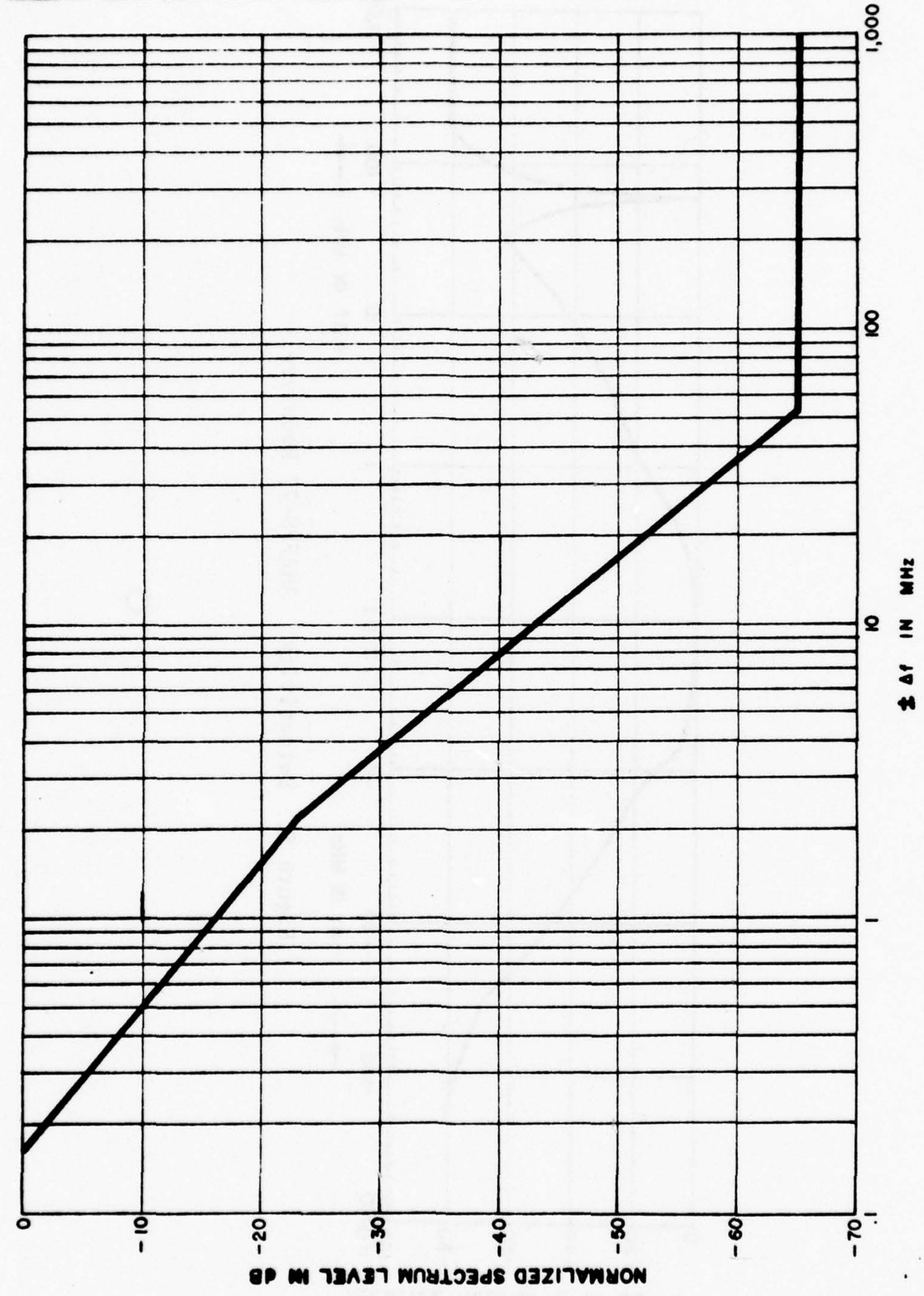

Figure 4. Emission spectrum: AVQ-10 transmitter.

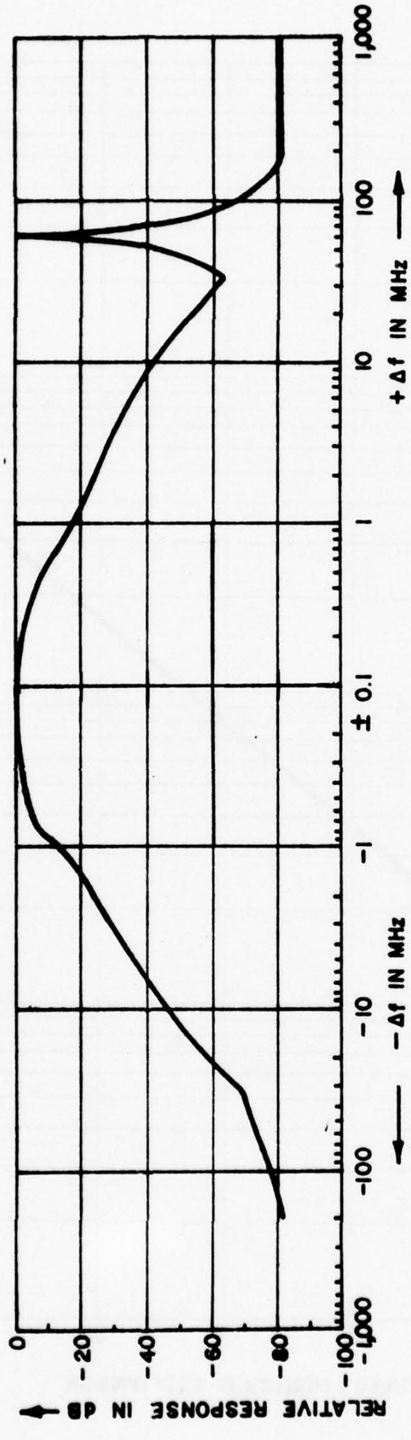

Figure 5. Selectivity: AN/FPS-77 Receiver.

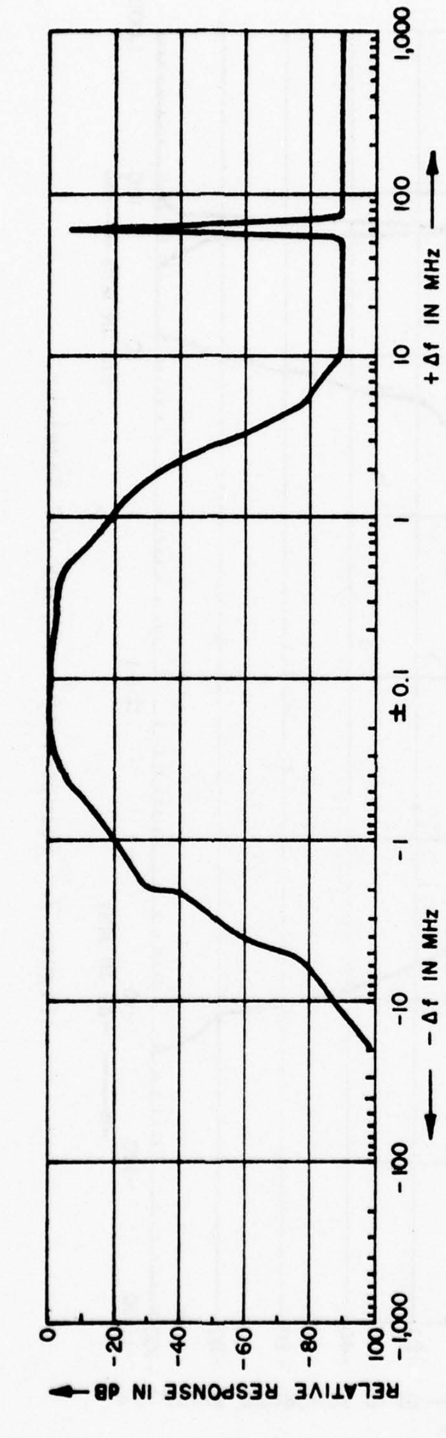

Figure 6. Selectivity: AN/TPS-40A Receiver.

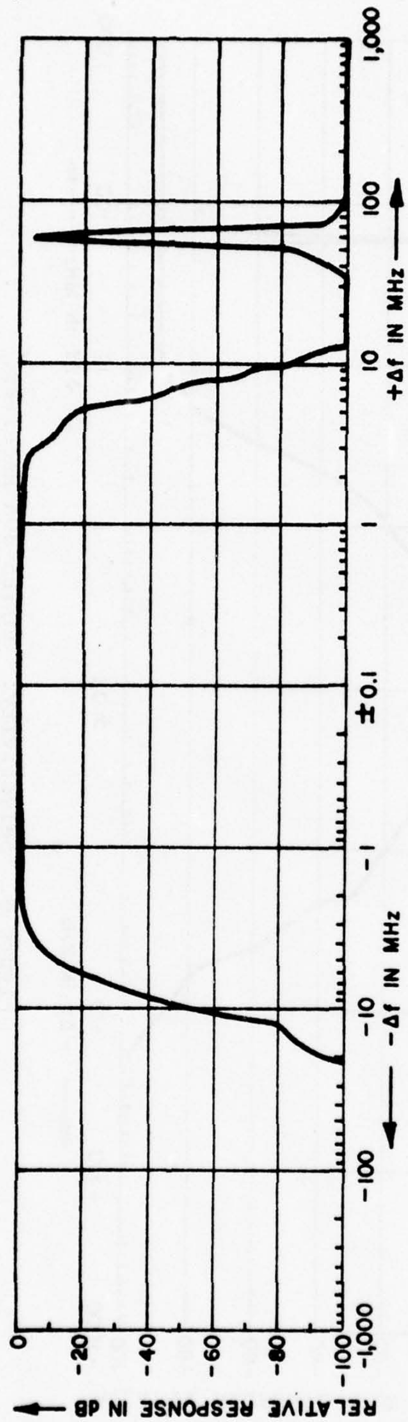

Figure 7. Selectivity: AN/SPS-10F Receiver.

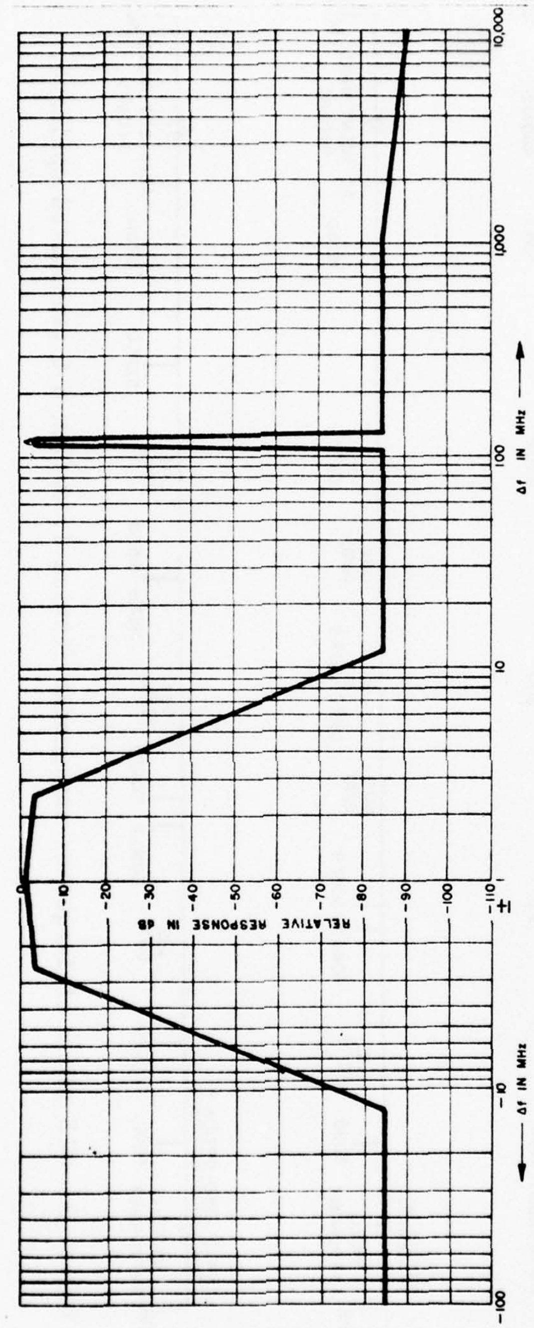

Figure 8. Selectivity: AVQ-10 Receiver.

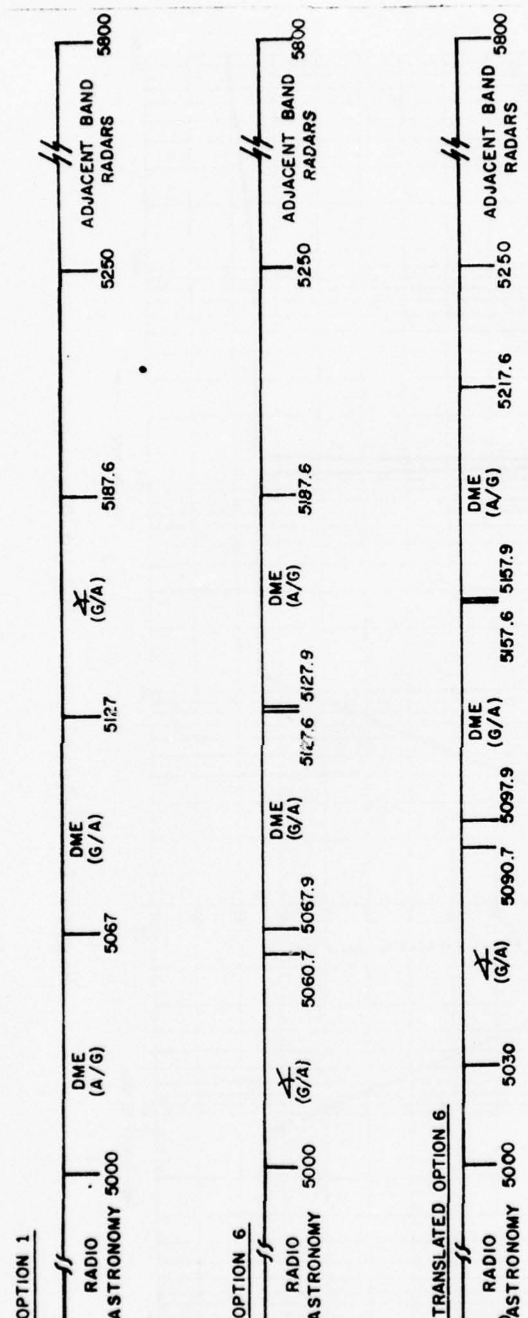

Figure 9. MLS plans of frequency assignment (option 1, option 6 & translated option 6.

6 differs from option 1 in that the angle information link is shifted to the lower end of the allocated spectrum. Translated option 6 is a version of option 6 with all components shifted 30 MHz toward the higher end of the spectrum. The advantage of this frequency translation is to provide equal frequency separation from adjacent-band systems at either end of the MLS band.

The MLS has three transmitters and three receivers which are capable of interacting with the adjacent-band radar equipments. The characteristics[2] of these equipments required for the interference analysis are listed in TABLES 2 and 3 and the transmitter emission spectra and receiver selectivities are given in Figure 10. The receiver selectivities have been calculated from data on the number of poles in the filters of the receiving equipment. The antenna gain specifications given are for the main beam.

RADARS TO MLS INTERACTIONS

Interference Aspects and Thresholds

The interference scenario and the number of interactions between the MLS and the radar systems are shown in Figure 11. The potential interference cases of primary concern (solid lines in Figure 11) are those between airborne equipments and those from airborne to ground equipments. Therefore, for a ground based radar, the two interactions of interest are those from radar transmitter to airborne MLS angle receiver and airborne MLS DME receiver. For the case of airborne radar, the three interactions of interest are from airborne radar transmitter to MLS airborne angle receiver, MLS airborne DME receiver and MLS ground based DME receiver. The interactions between ground based transmitters and receivers have not been considered because of siting and line-of-sight considerations.

One of the important analysis parameters for the MLS receivers is the interference threshold, which is taken as the average value. For these receivers the average values of interference to sensitivity ratio (derived from Reference 2) range from -2 dB to 14 dB as discussed later in this section. It is realized that the MLS parameters and interference thresholds are subject to changes as a result of testing or system design changes. Consequently, to accommodate these situations and for completeness sake, a wide range of Interference to Sensitivity ratio (IR_sR) average values (-40 dB to +60 dB, around the nominal value) have been considered in the present investigation to determine the overall impact of this parameter. The

TABLE 2

CHARACTERISTICS OF MLS TRANSMITTERS

Characteristics		Equipments		
		Angle Transmitter (Ground Based)	DME Transmitter (Ground Based)	DME Transmitter (Airborne)
Frequency (MHz)	Option 1	5127 to 5187	5067 to 5127	5000 to 5067
	Option 6	5000 to 5062	5067 to 5127	5127 to 5187
	Translated Option 6	5030 to 5092	5097 to 5157	5157 to 5217
Peak Output Power (dBm)		40	58	55
Antenna Gain Main Beam (dBi)		32	11	3
Beam Width 3 dB (Degrees)				
	E - Plane	1 to 2	20 to 35	20 to 35
	H - Plane	1 to 3	--	--
Emission Spectrum 3 dB Bandwidth (kHz)		24	1400	1400
Duty Cycle (dB)		-23	-24	-41

TABLE 3

CHARACTERISTICS OF MLS RECEIVERS

Characteristics		Equipments		
		Angle Receiver (Airborne)	DME Receiver (Airborne)	DME Receiver (Ground Based)
Frequency (MHz)	Option 1	5127 to 5187	5067 to 5127	5000 to 5067
	Option 6	5000 to 5061	5067 to 5127	5127 to 5187
	Translated Option 6	5030 to 5091	5097 to 5157	5157 to 5217
Antenna Gain (dBi)		12	3	11
Sensitivity (dBm)		-108	-93	-93

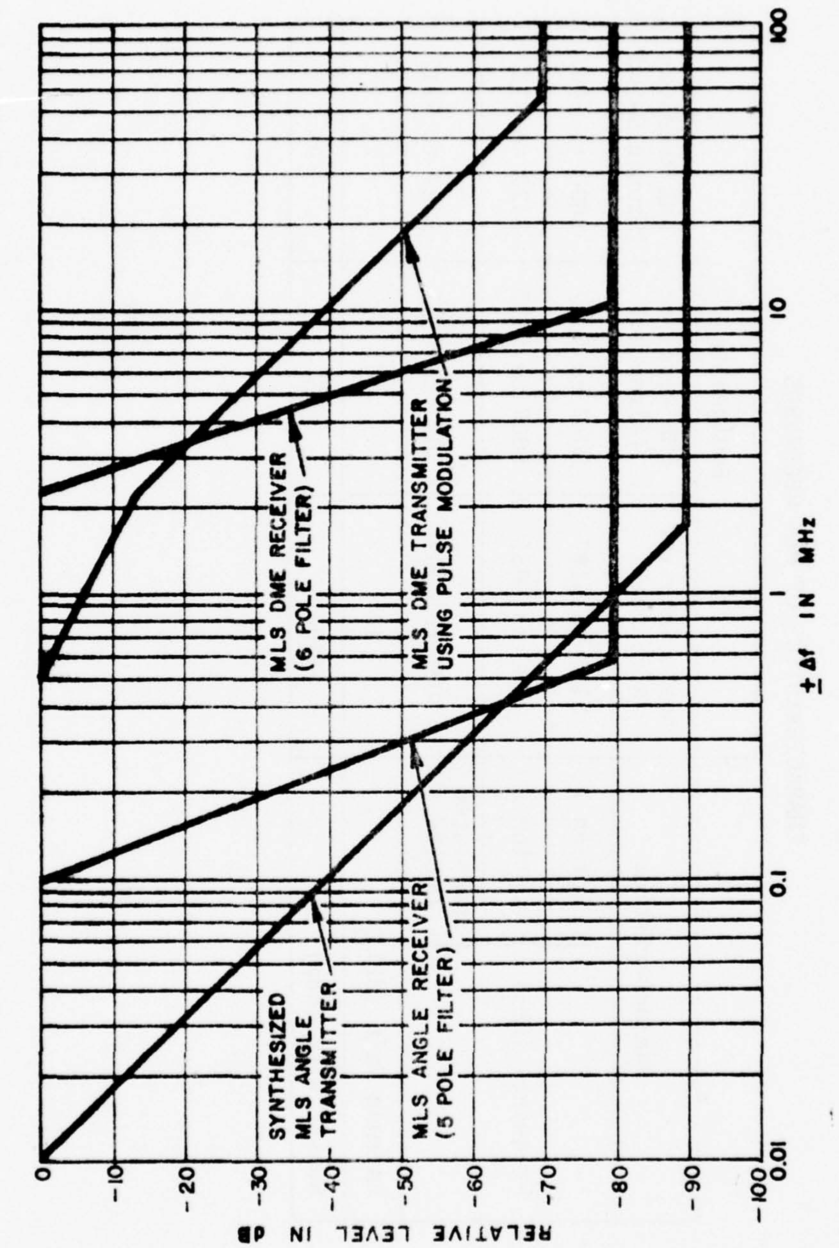

Figure 10. Emission spectra & selectivities for MLS equipment.

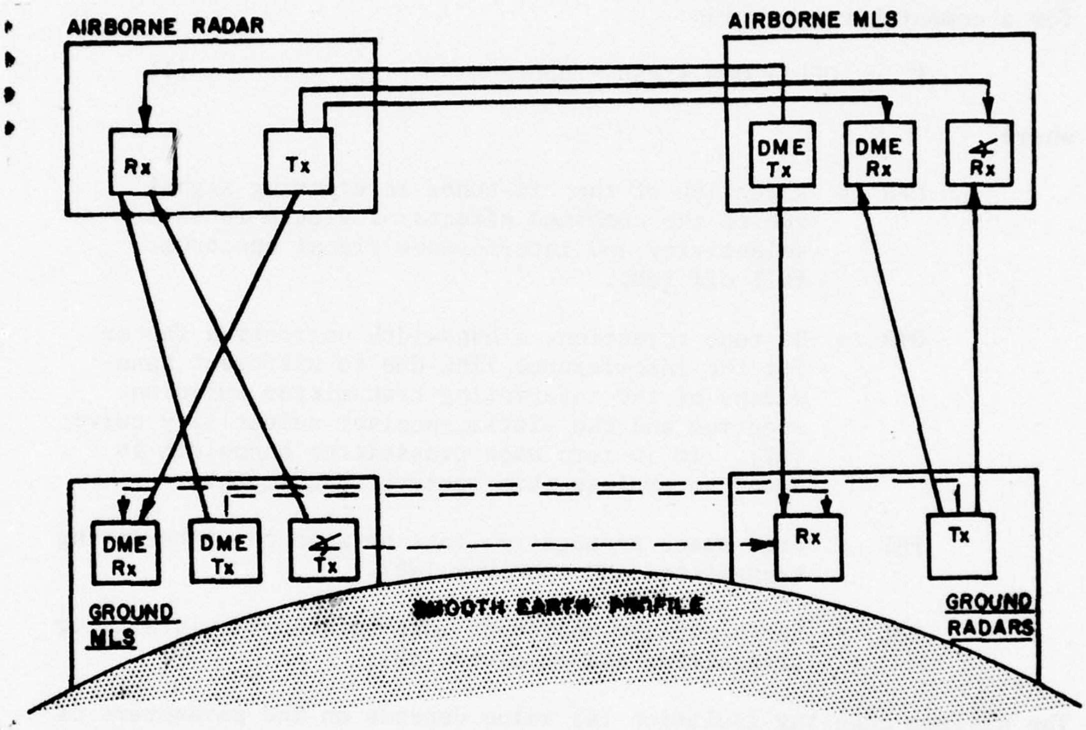

Figure 11. Interference scenario of MLS & adjacent band radars.

interfering transmitter and victim receiver antennas are considered to be of the same polarization and are represented by a two level pattern, i.e., main beam (MB) and sidelobe (SL).

Coupling Isolation

The coupling isolation (K) is a measure of minimum isolation required between the interfering transmitter and the victim receiver for satisfactory operation of the latter equipment. Mathematically, for a compatible operation:

$$K \leq OFR + OTR + FSL + ESL \tag{1}$$

where

OFR = Rejection of the off-tuned interfering signal due to the combined effects of victim receiver selectivity and interference signal spectrum fall off (dB).

OTR = On tune rejection, a bandwidth correction factor for the interference link due to different bandwidths of the interfering transmitter emission spectrum and the victim receiver selectivity curve (dB). It is zero when transmitter bandwidth is equal to or less than receiver bandwidth.

FSL = Free space propagation loss between the interfering transmitter and receiver (dB).

ESL = Earth surface dependent loss between the interferer transmitter and receiver (dB).

The minimum coupling isolation (K) value depends on the parameters of r.f. links to the victim equipment. Therefore, K is calculated from the equation containing the link parameters and the applicable interference threshold criterion.

For the case, in which signal to interference ratio (SIR) is specified as the interference criterion, the required K is calculated from the equation:

$$\begin{aligned} K = {} & [P_{TI} + G_{TI} + G_R + D_{UI}] + [SIR] \\ & - [P_{TS} + G_{TS} + G_R + D_{US} - L_{PS}] \end{aligned} \tag{2}$$

where

Subscript S denotes the parameters of the desired signal link

Subscript I denotes the parameters of the interference link

P_T = Peak output power of transmitter (dBm)

G_T = Main beam gain of the transmitter antenna in the direction of receiver (dBi)

G_R = Main beam gain of receiver antenna in the direction of transmitter (dBi)

D_U = Duty cycle associated with transmitter equipment (dB)

L_{PS} = Path loss (free space and earth surface) of the signal link (dB)

SIR = Required average value signal to interference ratio (dB).

For the case in which the interference threshold criterion is expressed as interference to sensitivity ratio (IR_sR), the required coupling isolation, K, can be determined from the equation

$$K = [P_{TI} + G_{TI} + G_R + D_{UI}] - [R_S + IR_sR] \qquad (3)$$

where

R_S = Sensitivity of the receiver (dBm)

IR_sR = Required average value of interference to sensitivity ratio (dB).

It can be seen from Equations (2) and (3) that interference thresholds in terms of SIR and IR_sR are mutually convertible through the coupling isolation value. This approach is used to convert the composite interference threshold (Reference 2) data of MLS receivers into a uniform representation in terms of IR_sR. This conversion is helpful for evaluation, comparison and interpretation of the analysis data. TABLE 4 presents the interference thresholds of MLS receivers in the IR_sR form. An example illustrating the conversion process of SIR data into IR_sR data for the MLS angle receiver is given below:

From Equations (2) and (3) it can be shown that:

$$IR_sR = A - SIR - L_{PS} - R_S \quad (4)$$

where

$A = P_{TS} + G_{TS} + D_U + G_R$

$= 40$ dBm + 32 dB - 23 dB + 12 dB = 61 dBm

= is the average r.f. power in the MLS angle transmitter and the MLS angle receiver link for the main beams coupling

SIR = 15 dB (average value)

R_S = -108 dBm

L_{PS} = 140 dB

= The maximum path loss (therefore, minimum signal) between the ground based MLS transmitter and airborne MLS angle receiver when the aircraft is within the MLS range of 20 n. miles and 20,000 feet altitude. A computer-modeling program was used to compute this path loss.

Substituting the values of these terms in Equation (4) yields an IR_sR of 14 dB.

TABLE 4

INTERFERENCE THRESHOLDS (AVERAGE VALUES) OF MLS RECEIVERS

MLS Receiver	Interference Threshold IR_sR (dB)	Interference Threshold (dB) from Reference 2
Angle Guidance (Airborne)	14	SIR = 15
DME (Ground Based)	0	$IR_sR = 0$
DME (Airborne)	- 2	SIR = 3

TABLE 5 lists the range of coupling isolation values calculated for radars to MLS interactions. The system parameters for computing these values, using Equation (3), were taken from TABLES 1 to 3.

OFR and Frequency Distance Curves

The OFR curves depict the attenuation experienced by the interfering signal as a function of off-tuning from the receiver tuned frequency. Essentially the receiver selectivity is combined with the transmitter emission spectrum to derive the OFR. ECAC's computer program OFRCAL contains the capability for OFR and frequency distance analysis when a transmitter emission spectrum and receiver selectivity are provided as point sets. Program OFRCAL was, therefore, used to determine the OFR curves for the radars to MLS interactions. An example of an OFR curve is shown in Figure 12. Typical values of OFR for MLS options 1 and 6 range from 50 dB to 66 dB for minimum frequency separation between the equipments.

In each case a minimum total isolation (given in TABLE 5) must be maintained between the MLS receivers and the radar system transmitters at some degree of frequency separation. For the situations where the minimum isolation is greater than OFR loss, the OFRCAL program can be used to determine the remaining loss which must be made up by a distance separation and OTR between the radar transmitters and the MLS receivers. By combining the OFR curve with the transmitter power, antenna gain and other system parameters described in Equation (3) the total minimum isolation minus OFR is converted to distance separation based on a smooth 4/3 earth profile. This was done for each Δf (separation between radar transmitter frequency and MLS receiver frequency) specified in the three MLS plans of frequency assignment. The end result is a curve defining the relationship between separation frequency Δf and separation distance required to maintain the minimum total isolation for the interference link.

For this analysis the radar transmitters emission spectra, shown in Figures 1 through 4, were used together with the MLS receivers selectivity curves from Figure 10. The set of Frequency Distance (F/D) curves generated for this case are presented in APPENDIX A (Figures A-1 to A-8). An example of an F/D plot is shown in Figure 13. From electromagnetic compatibility considerations, the frequency/distance values falling in the area below the prescribed K-value curve are to be avoided. For smaller values of K, the (F/D) plot approaches the abcissa, which corresponds to a collocation situation. Small values of K result from low interfering transmitter power and/or low sensitivity equipments which can withstand high levels of interference signals.

TABLE 5

COUPLING ISOLATION DATA CALCULATED FOR RADARS TO MLS INTERACTIONS

Case Number	From		To	Range of K Values (dB)
1	Ground Radar Transmitters	AN/FPS-77	MLS Angle Receiver (Airborne)	249 to 149
		AN/TPS-40A		262 to 162
		AN/SPS-10F		237 to 137
2	Ground Radar Transmitters	AN/FPS-77	MLS DME Receiver (Airborne)	225 to 125
		AN/TPS-40A		238 to 138
		AN/SPS-10F		214 to 114
3	AVQ-10 Transmitter (Airborne)		Angle Receiver (Airborne)	235 to 135
4	AVQ-10 Transmitter (Airborne)		DME Receiver (Airborne)	211 to 111
5	AVQ-10 Transmitter (Airborne)		DME Receiver (Ground Based)	219 to 119

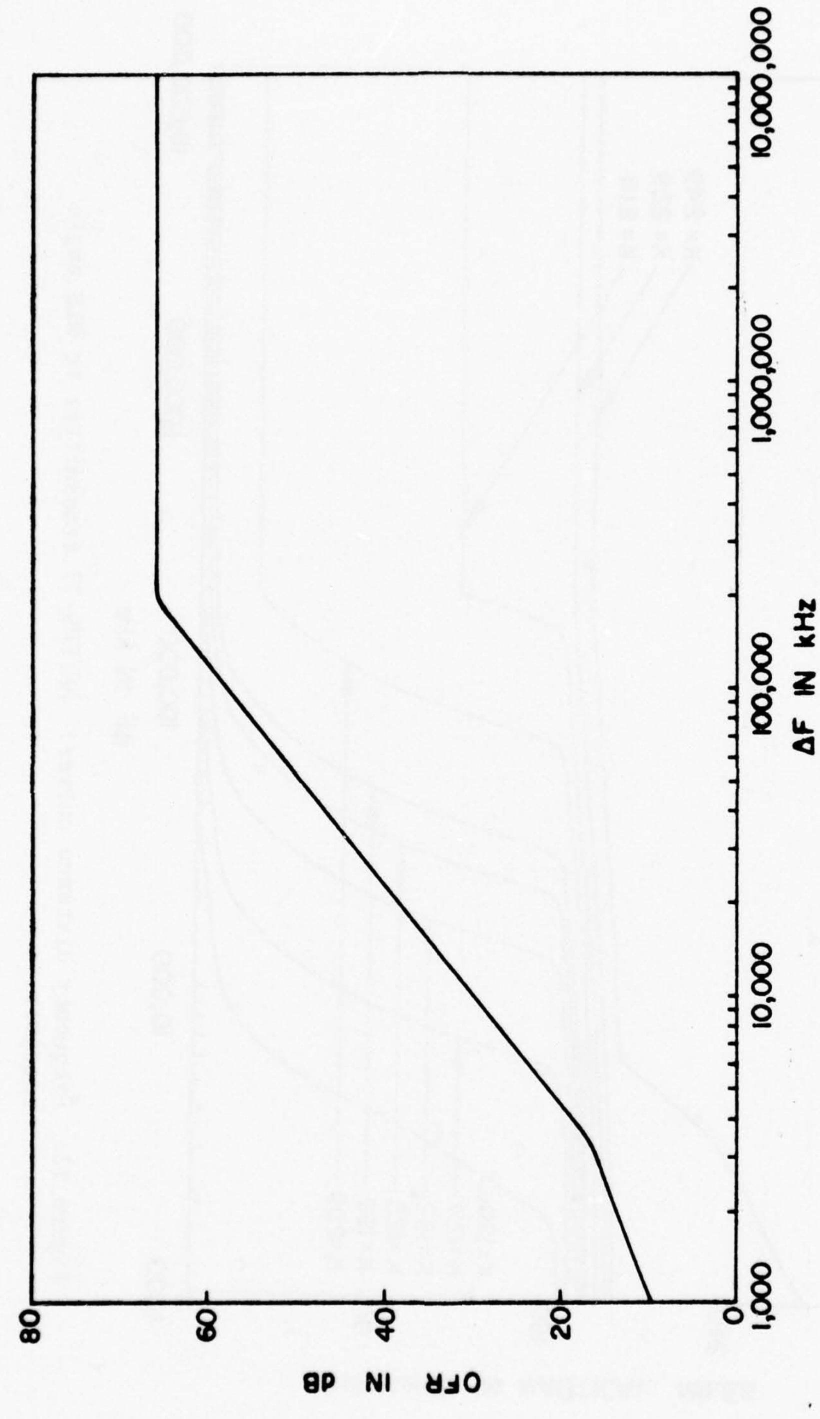

Figure 12. OFR curve: AN/FPS-77 transmitter to MLS angle receiver.

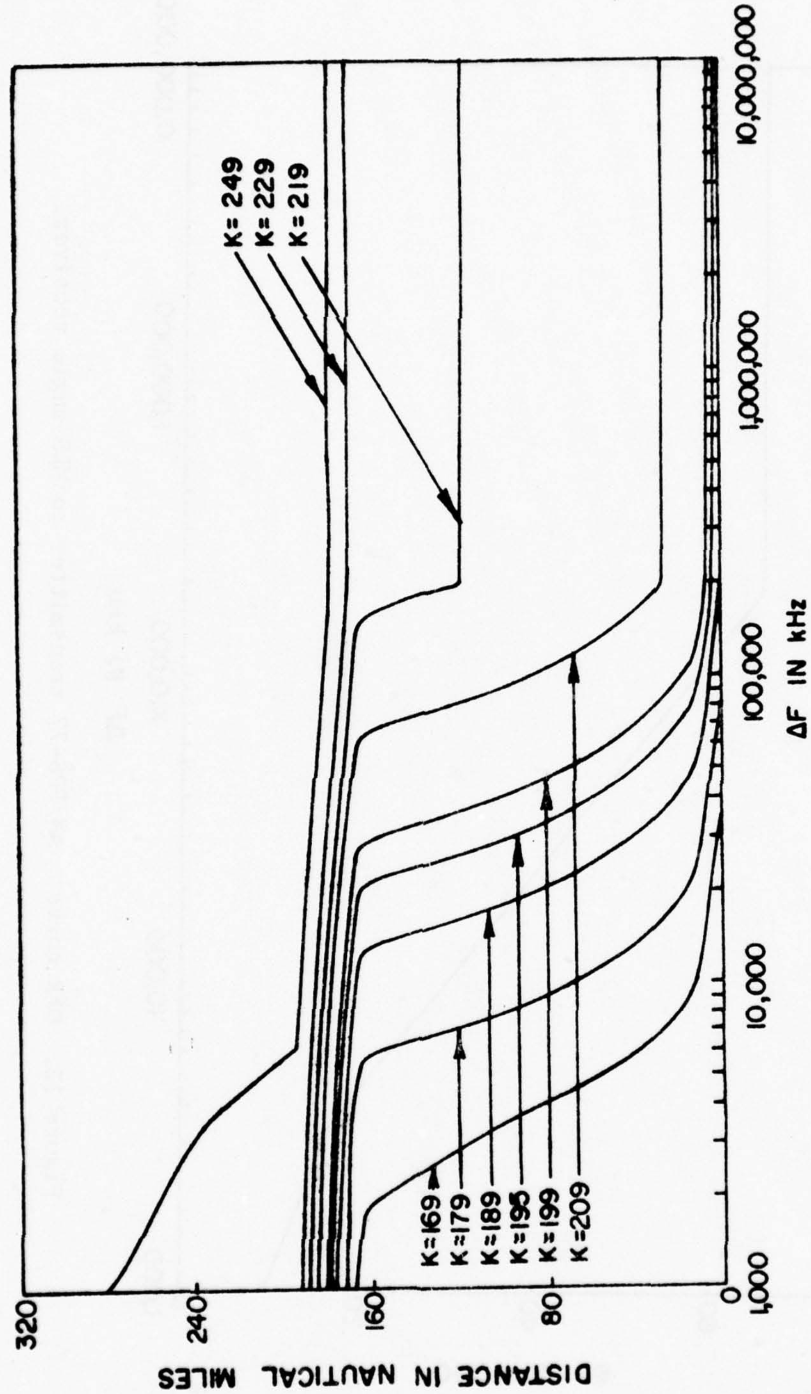

Figure 13. Frequency distance curves: AN/FPS-77 transmitter to MLS angle receiver.

MLS TO RADARS INTERACTIONS

Interference Aspects and Thresholds

From Figure 11 it may be seen that the interactions of interest from the MLS to radar systems are the following:

1. MLS to ground radar.
    a. Airborne DME transmitter to ground radar receiver.
2. MLS to airborne radar.
    a. Ground angle transmitter to airborne radar receiver.
    b. Ground DME transmitter to airborne radar receiver.
    c. Airborne DME transmitter to airborne radar receiver.

The radar systems under analysis remain the same.

Since radar receivers detect peak signal levels, peak powers of MLS transmitters are considered. Therefore, the interference criterion for this case is the peak values of interference to sensitivity ratio. The modified equation, used to calculate the coupling isolation value is given as:

$$K = [P_{TI} + G_{TI} + G_R] - R_S - IR_sR \qquad (5)$$

The various terms in Equation 5 are already identified and their values are given in TABLES 1 and 2. Again for completeness sake, the coupling isolation values listed in TABLE 6 were calculated for a range of IR_sR peak values from -40 dB to +60 dB around the nominal value.

OFR and Frequency Distance Curves

The emission spectrum of MLS transmitters and the receiver selectivity curves of the radar systems are given in Figures 10 and 5 through 8 respectively. The calculated values of coupling isolation are tabulated in TABLE 6. The data from these curves and TABLE 6 were used in the OFRCAL program to generate OFR and F/D curves. The F/D curves are shown in APPENDIX A (Figures A-9 through A-13). The representative curves for this case are given in Figures 14 and 15. The OFR values for MLS versus radars range from 64 dB to 71 dB for the MLS options 1 and 6 for minimum frequency separation between the equipments.

SUMMARY OF ANALYSIS DATA

The analysis data is presented for a large range of both IR_sR and K values in TABLES 7 and 8. These tables were derived from the data contained in the OFR and F/D curves. The data is given in terms

TABLE 6

COUPLING ISOLATION DATA CALCULATED FOR MLS TO RADARS INTERACTIONS

Case Number	From	To		Range of K Values (dB)
1	MLS DME Transmitter (Airborne)	Ground Radar Receiver	AN/FPS-77	243 to 143
			AN/TPS-40A	250 to 150
			AN/SPS-10F	224 to 124
2	DME Transmitter (Airborne)	AVQ-10 Receiver (Airborne)		226 to 126
3	Angle Transmitter (Ground)	AVQ-10 Receiver (Airborne)		240 to 140
4	DME Transmitter (Ground)	AVQ-10 Receiver (Airborne)		237 to 137

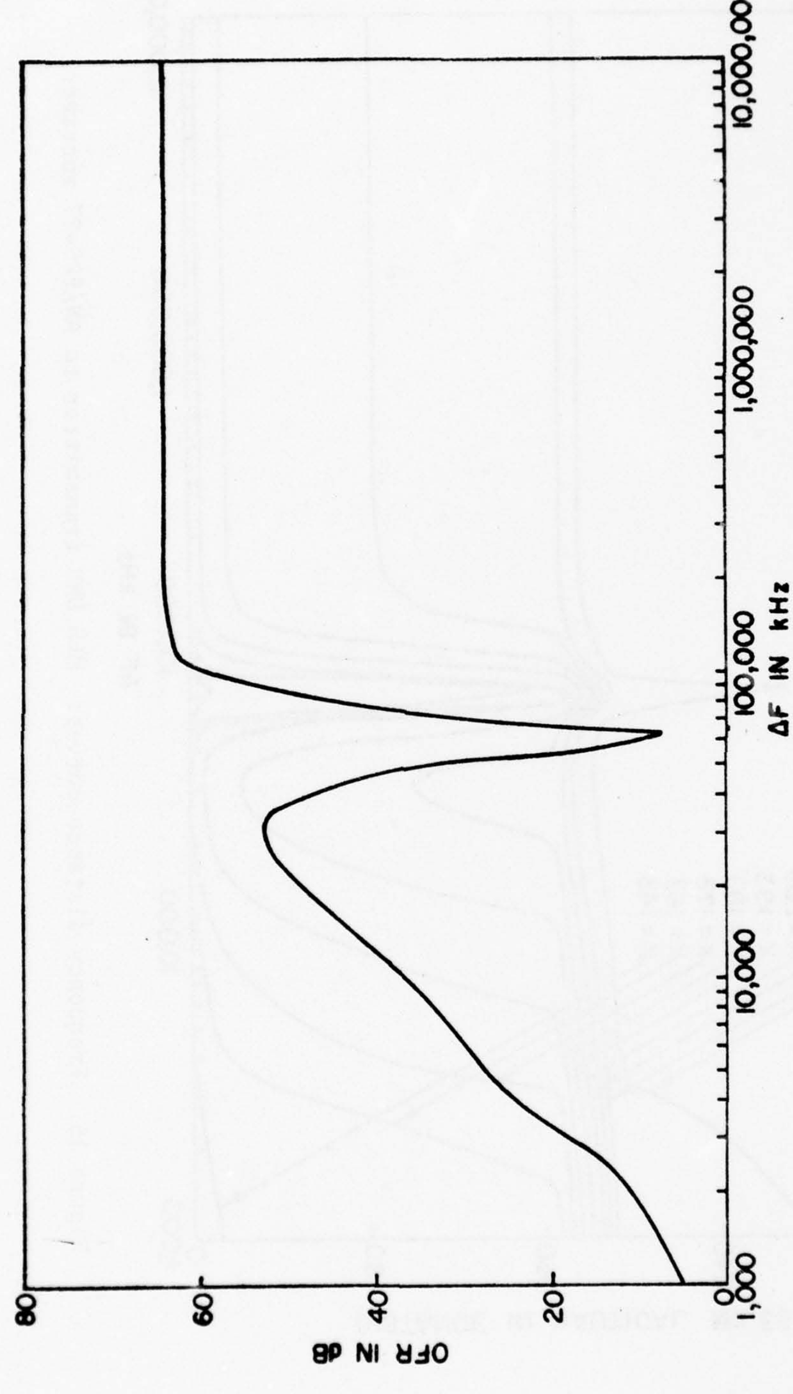

Figure 14. OFR curve: MLS DME transmitter to AN/FPS-77 receiver.

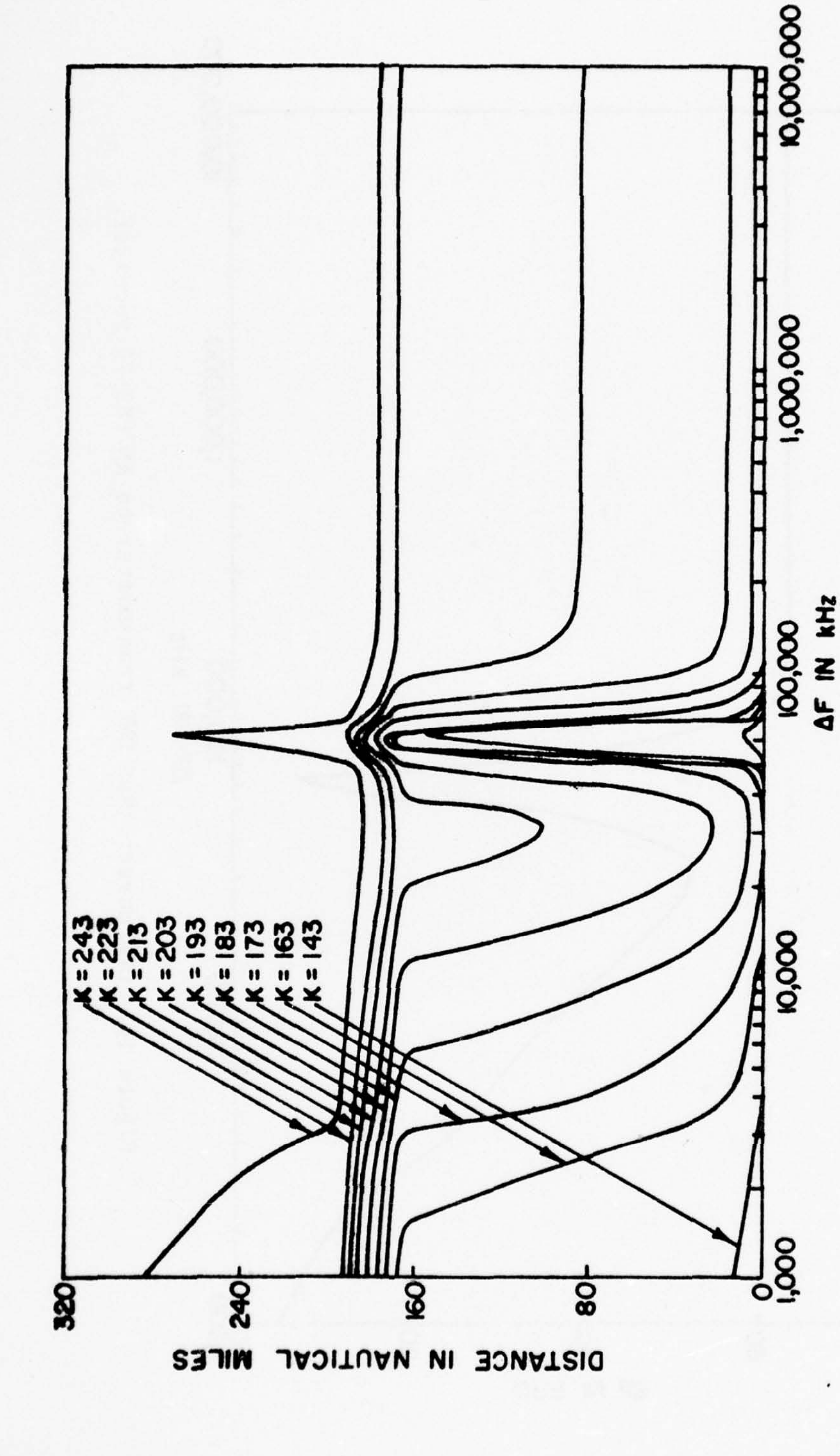

Figure 15. Frequency distance curves: MLS DME transmitter to AN/FPS-77 receiver.

TABLE 7

SEPARATION DISTANCE DATA CALCULATED FOR RADARS TO MLS INTERACTIONS AT MINIMUM SEPARATION FREQUENCY

Radar	Frequency Assignment Options	MLS Equipment: Angle Receiver (Airborne) Distance for IR_sR Values[a]									DME Receiver (Airborne) Distance for IR_sR Values[a]								DME Receiver (Ground) Distance for IR_sR Values[a]				
		-40	-20	-10	0	10	14	20	30	40	-40	-20	-10	-2	0	10	20	30	-40	-20	-10	0	10
AN/FPS-77	K-Values	249	229	219	209	199	195	189			225	205	195	187	185	175							
	Option 1	179 (332)	170 (315)	119 (220)	27 (50)	6.9 (13)	4.2 (8)	Δ[b]			173 (320)	74 (137)	14 (26)	5.9 (11)	4.5 (8.3)	Δ							
	Option 6	179 (332)	170 (315)	119 (220)	27 (50)	6.9 (13)	4.2 (8)	Δ[b]			173 (320)	74 (137)	14 (26)	5.9 (11)	4.5 (8.3)	Δ							
	Translated Option 6	179 (332)	170 (315)	119 (220)	27 (50)	6.9 (13)	4.2 (8)	Δ[b]			173 (320)	74 (137)	14 (26)	5.9 (11)	4.5 (8.3)	Δ							
AN/TPS-40A	K-Values	262	242	232	222	212	208	202	192	182	248	228	208	200	198	188	178	168					
	Option 1	188 (348)	180 (333)	175 (324)	171 (317)	155 (287)	91 (169)	38 (70)	8.5 (16)	1.6 (3)	185 (343)	176 (326)	164 (304)	59 (109)	45 (83)	9.4 (17)	2.4 (4.4)	Δ					
	Option 6	186 (344)	177 (328)	172 (319)	168 (311)	66 (122)	36 (67)	12 (22)	4 (7.4)	Δ	187 (346)	179 (332)	170 (315)	151 (280)	114 (211)	26 (48)	6.8 (12.6)	Δ					
	Translated Option 6	186 (344)	177 (328)	172 (319)	168 (311)	66 (122)	36 (67)	12 (22)	4 (7.4)	Δ	190 (352)	183 (339)	174 (322)	170 (315)	169 (313)	102 (189)	22 (41)	6.2 (11.5)					
AN/SPS-10F	K-Values	237	211	207	197	187					224	204	184	176	174	164							
	Option 1	174 (322)	57 (106)	31 (57)	7 (13)	Δ					172 (319)	56 (104)	4 (7.4)	Δ	Δ	Δ							
	Option 6	172 (319)	26 (48)	12 (22)	4 (7.4)	Δ					174 (322)	130 (241)	7 (13)	1.3 (2.4)	Δ	Δ							
	Translated Option 6	173 (320)	31 (57)	15 (28)	4.7 (8.7)	Δ					176 (326)	156 (291)	8 (15)	3 (5.6)	1.7 (3.1)	Δ							
AVQ-10	K-Values	235	215	205	195	185	181	175	165	155	211	191	181	173	171	161	151	141	219	199	189	179	169
	Option 1	345 (639)	132 (244)	27 (50)	10.5 (19)	3.7 (6.8)	2.4 (4.4)	1.2 (2.2)	.4 (.74)	.1 (.18)	215 (398)	16 (29.6)	6 (11)	2.5 (4.6)	2 (3.7)	.6 (1.1)	.2 (.37)	Δ	211 (391)	70 (130)	13 (24)	4.3 (8)	Δ
	Option 6	344 (637)	84 (156)	19 (35)	7.6 (14)	2.6 (4.8)	1.6 (2.9)	.8 (1.5)	.3 (.6)	Δ	285 (527)	22 (41)	9 (17)	3.7 (6.9)	3 (5.6)	1 (1.9)	.3 (.56)	.1 (.19)	211 (391)	70 (130)	13 (24)	4.3 (8)	Δ
	Translated Option 6	344 (637)	90 (167)	20 (37)	8 (15)	2.7 (5)	1.7 (3.1)	.9 (1.7)	.3 (.6)	Δ	320 (509)	26 (48)	10 (18.6)	4.6 (8.5)	3.5 (6.5)	1.2 (2.2)	.4 (.74)	.1 (.19)	211 (391)	81 (150)	16 (29.6)	5 (9.3)	Δ

[a] Distances are given in Nautical miles, the numbers in parenthesis are in kilometers.

[b] Δ denotes a nominal distance; typically, a small fraction of a nautical mile.

TABLE 8

SEPARATION DISTANCE DATA CALCULATED FOR MLS TO RADARS INTERACTIONS AT MINIMUM SEPARATION FREQUENCY

Radar	Frequency Assignment Options	MLS Equipment: DME Transmitter (Airborne) Distance for IR_sR Values								DME Transmitter (Ground) Distance for IR_sR Values						ANGLE Transmitter (Ground) Distance for IR_sR Values					
		-40	-20	-10	0	10	20	30	40	-40	-20	-10	0	10	20	-40	-20	-10	0	10	20
AVQ-10	K-Values	226	206	196	186	176	166	156	146	237	217	207	197	187	177	240	220	210	200	190	180
	Option 1	318 (589)	25 (46)	10.2 (18.8)	3.6 (6.6)	1.2 (2.2)	.4 (.7)	.1 (.18)	Δ	175 (324)	164 (304)	43 (80)	9.3 (17)	2.3 (4.3)	Δ	175 (324)	138 (256)	33 (61)	7.7 (14)	.5 (.93)	Δ
	Option 6	318 (589)	25 (46)	10.2 (18.8)	3.6 (6.6)	1.2 (2.2)	.4 (.7)	.1 (.18)	Δ	175 (324)	164 (304)	43 (80)	9.3 (17)	2.3 (4.3)	Δ	175 (324)	138 (256)	33 (61)	7.7 (14)	.5 (.93)	Δ
	Translated Option 6	318 (589)	25 (46)	10.2 (18.8)	3.6 (6.6)	1.2 (2.2)	.4 (.7)	.1 (.18)	Δ	175 (324)	164 (304)	43 (80)	9.3 (17)	2.3 (4.3)	Δ	175 (324)	138 (256)	33 (61)	7.7 (14)	.5 (.93)	Δ
AN/FPS-77	K-Values	243	223	213	203	193	183														
	Option 1	175 (324)	169 (313)	84 (156)	17.1 (32)	5.2 (9.6)	Δ														
	Option 6	175 (324)	169 (313)	84 (156)	17.1 (32)	5.2 (9.6)	Δ														
	Translated Option 6	175 (324)	169 (313)	84 (156)	17.1 (32)	5.2 (9.6)	Δ														
AN/TPS-40	K-Values	250	230	220	210	200	190	180	170												
	Option 1	181 (335)	172 (319)	166 (307)	55.7 (103)	10.7 (20)	3.3 (6.1)	Δ	Δ												
	Option 6	181 (335)	188 (348)	184 (341)	179 (332)	175 (324)	170 (315)	144 (267)	34 (63)												
	Translated Option 6	181 (335)	176 (326)	171 (317)	160 (296)	51 (94)	10.1 (19)	2.9 (5.4)	Δ												
AN/SPS-10F	K-Values	224	204		194	184															
	Option 1	170 (315)	27 (50)		6.9 (13)	Δ															
	Option 6	170 (315)	27 (50)		6.9 (13)	Δ															
	Translated Option 6	170 (315)	27 (50)		6.9 (13)	Δ															

[a]Distances are given in Nautical miles, the numbers in parenthesis are in kilometers.

[b]Δ denotes a nominal distance; typically, a small fraction of a nautical mile.

of the minimum separation distance with IR_sR (or K value) as the parameter for the three plans of frequency assignment.

The use of TABLES 7 and 8 is illustrated by considering the following example. The distance constraints are to be determined for compatible operation between the AN/TPS-40A radar and the DME airborne receiver for the various coupling combinations between the main beams and the sidelobes for the three frequency assignment plans. It is given that the airborne DME receiver has an average interference threshold (IR_sR = -2 dB), and a sidelobe level of 0 dB. The radar has a sidelobe level of 22 dB below the main beam level. The first step in the solution is to determine the coupling isolation value of the given equipment for main beam to main beam coupling. Inserting the values of equipment parameters from TABLES 1 and 3 and the given data in Equation (3), yields:

$$K = [90 + 43 + 3 - 31] - [-93 - 2] = 200 \text{ dB}$$

Entering TABLE 7 with K=200 for the interacting equipment pair indicates that the distance constraint values for compatible operation for translated option 6, option 6 and option 1 are 170, 151 and 59 nautical miles respectively.

For the case of radar sidelobe to MLS receiver main beam coupling, the value of K is:

$$K = [90 + 21 + 3 - 31] - [-93 - 2] = 178 \text{ dB}$$

Again entering TABLE 7 for K=178 gives the values of distance constraints of 22, 6.8, 2.4 nautical miles for the frequency plans of translated option 6, option 6 and option 1 respectively. The situation of main beam to main beam coupling has a low probability of occurrence and provides the worst case results of distance constraints.

The OFR data for the three frequency assignment plans is summarized in TABLES 9 and 10 for the cases of radars to MLS and MLS to radars interactions. These tables provide a comprehensive summary of contributions to coupling isolation due to the off-frequency effects of the interfering transmitters and victim receivers.

RESULTS

The distance constraints data in TABLES 11 to 14 is extracted from the main TABLES 7 and 8. The results are described here under the two cases of "Radars to MLS Interactions" and "MLS to Radars Interaction."

TABLE 9

OFR DATA CALCULATED FOR RADARS TO MLS INTERACTIONS

Radars	Frequency Assignment Options	MLS Equipment: Angle Receiver (Airborne)		DME Receiver (Airborne)		DME Receiver (Ground)	
		Minimum Separation Frequency (MHz)	OFR (dB)	Minimum Separation Frequency (MHz)	OFR (dB)	Minimum Separation Frequency (MHz)	OFR (dB)
AN/FPS-77	Option 1	263	66	383	59.8		
	Option 6	389	66	263	59.8		
	Translated Option 6	359	66	233	59.8		
AN/TPS-40A	Option 1	63	58.2	183	56.7		
	Option 6	189	64.5	63	50		
	Translated Option 6	159	64.5	33	40.9		
AN/SPS-10F	Option 1	263	55.2	383	60		
	Option 6	389	60.3	263	55		
	Translated Option 6	359	59.1	233	53.5		
AVQ-10	Option 1	193	61.3	313	55.9	253	54.4
	Option 6	319	64.6	193	52.4	253	54.4
	Translated Option 6	289	64.1	163	50.4	223	53.4

TABLE 10

OFR DATA CALCULATED FOR MLS TO RADARS INTERACTIONS

		MLS Equipment					
Radars	Frequency Assignment Options	DME Transmitter (Airborne) Minimum Separation Frequency (MHz)	OFR (dB)	DME Transmitter Minimum Separation Frequency (MHz)	OFR (dB)	Angle Transmitter Minimum Separation Frequency (MHz)	OFR (dB)
AVQ-10 (Airborne)	Option 1	313	66	253	66	193	71
	Option 6	193	66	253	66	319	71
	Translated Option 6	163	66	223	66	289	71
AN/FPS-77	Option 1	383	64.1				
	Option 6	263	64.1				
	Translated Option 6	233	64.1				
AN/TPS-40A	Option 1	183	66.1				
	Option 6	63	29.4				
	Translated Option 6	33	58				
AN/SPS-10F	Option 1	383	65.9				
	Option 6	263	65.9				
	Translated Option 6	233	65.9				

TABLE 11

DISTANCE CONSTRAINTS FOR COMPATIBILITY AT MINIMUM SEPARATION FREQUENCY FROM RADARS TO MLS USING OPTION 1 PLAN @ $-2 \leq IR_sR \text{ (dB)} \leq 14$

	Interacting Systems			
Type of Coupling	Distance Between Meteorological Radars to MLS[a]	Distance Between Height Finding Radars to MLS	Distance Between Ship & Shore Search Radars to MLS	Distance Between Airborne Radars to MLS
Radar Main beam to MLS Main beam	5.9 (10.9)	91 (168.5)	Nominal	4.3 (7.9)
Radar Sidelobe (-20 dB) to MLS Main beam	Nominal[b]	5.7 (10.6)	Nominal	Nominal
Radar Sidelobe (-20 dB) to MLS Sidelobe (-10 dB)	Nominal	Nominal	Nominal	Nominal

[a]Distances are given in Nautical miles, the numbers in parenthesis are in kilometers.

[b]Typically, a small fraction of a nautical mile.

TABLE 12

DISTANCE CONSTRAINTS FOR COMPATIBILITY AT MINIMUM SEPARATION FREQUENCY FROM RADARS TO MLS USING OPTION 6 PLANS @ $-2 \leq IR_sR \text{ (dB)} \leq 14$

	Interacting Systems			
Type of Coupling	Distance from Meteorological, Weather Radar to MLS[a]	Distance from Height Finding Radars to MLS	Distance from Ship & Shore Search Radars to MLS	Distance from Airborne Radars to MLS
Radar Main beam to MLS Main beam	5.9 (10.9)	Option 6 → 151 (230) Translated Option 6 → 170 (315)	Option 6 → 1.3 (2.4) Translated Option 6 → 3 (5.6)	Option 6 → 4.3 (7.9) Translated Option 6 → 5 (9.26)
Radar Sidelobe (-20 dB) to MLS Main beam	Nominal[b]	Option 6 → 7 (13) Translated Option 6 → 25 (46.3)	Nominal	Nominal
Radar Sidelobe (-20 dB) to MLS Sidelobe (-10 dB)	Nominal	Option 6 → Nominal Translated Option 6 → 7 (13)	Nominal	Nominal

[a] Distances are given in Nautical miles, the numbers in parenthesis are in kilometers.

[b] Typically, a small fraction of a nautical mile.

TABLE 13

DISTANCE CONSTRAINTS FOR COMPATIBILITY AT MINIMUM SEPARATION FREQUENCY FROM MLS TO RADARS USING OPTION 1 PLAN @ ZERO dB IR_sR

Type of Coupling	Interacting Systems: Distance from MLS to Meteorological Radars[a]	Distance from MLS to Height Finding Radars	Distance from MLS to Ship & Shore Search Radars	Distance from MLS to Airborne Radars
Radar Mainbeam to MLS Main beam	17.1 (31.7)	55.7 (103)	6.9 (12.8)	9.3 (17.2)
Radar Sidelobe (-20 dB) to MLS Main beam	Nominal[b]	3.3 (5.1)	Nominal	Nominal
Radar Sidelobe (-20 dB) to MLS Sidelobe (-10 dB)	Nominal	Nominal	Nominal	Nominal

[a]Distances are given in Nautical miles, the numbers in parenthesis are in kilometers.

[b]Typically, a small fraction of a nautical mile.

TABLE 14

DISTANCE CONSTRAINTS FOR COMPATIBILITY AT MINIMUM SEPARATION FREQUENCY FROM MLS TO RADARS USING OPTION 6 PLANS @ ZERO dB IR_sR

	Interacting Systems			
Type of Coupling	Distance from MLS to Meteorological Radars[a]	Distance from MLS to Height Finding Radars	Distance from MLS to Ship & Shore Search Radars	Distance from MLS to Airborne Radars
Radar Main beam to MLS Main beam	17.1 (31.7)	Option 6 → 179 (331) Translated Option 6 → 160 (296)	6.9 (12.8)	9.3 (17.2)
Radar Sidelobe (-20 dB) to MLS Main beam	Nominal[b]	Option 6 → 170 (315) Translated Option 6 → 10.1 (18.7)	Nominal	Nominal
Radar Sidelobe (-20 dB) to MLS Sidelobe (-10 dB)	Nominal	Option 6 → 144 (266) Translated Option 6 → 2.9 (5.4)	Nominal	Nominal

[a]Distances are given in Nautical miles, the numbers in parenthesis are in kilometers.

[b]Typically, a small fraction of a nautical mile.

Results of Radars to MLS Interactions

The potential for interference from various radar categories can be assessed in terms of distance separations listed in TABLES 11 and 12 for the MLS frequency assignment options. The main results are:

1. For the most likely situation of sidelobe to sidelobe coupling, the distance constraints between radar and MLS are of nominal value.

2. The separation distance requirements for frequency assignment options 1 and 6 are equal for the majority of the interactions between radars and MLS equipments.

3. Option 6 has some advantage over translated option 6.

4. Main beam to main beam coupling can be expected between the airborne C-band radar and the ground C-band MLS DME receiver during the final approach phase of the landing aircraft. For this situation, the minimum distance requirements, specified herein, cannot be maintained. The C-band MLS DME vulnerability to the radar signal format has not been determined. If L-band, (962 to 1213 MHz) DME is not substituted to perform the ranging functions, further studies on the possible degradation of the C-band DME in this situation will be required.

5. The Ship and Shore Search radars require the least separation distance from MLS compared to other categories of radars.

Results of MLS to Radars Interactions

The impact of MLS equipment on adjacent band radars is also judged in terms of the distance constraints listed in TABLES 13 and 14 for the MLS frequency assignment options. The results are:

1. The potential for interference is independent of the frequency assignment options, in the majority of cases.

2. The equipments can operate compatibly in the same environment for the most likely situation of sidelobe to sidelobe coupling.

3. One exception is an option 6 case wherein the separation distance requirement between MLS and height-finding radars is large because the location of first image frequency overlaps the minimum separation frequency between the interacting equipments. This effect can be avoided by using option 1 frequency plan.

SECTION 3

CONCLUSIONS

With one exception the separation distance constraints between TRSB MLS and radars in the 5.25 to 5.8 GHz band are not overly re-trictive. The exception is the main beam to main beam interaction between airborne C-band radars and the ground, C-band, MLS Distance Measuring Equipment (DME) transponder which is likely to occur during the aircraft's final approach. The result of this interaction is based upon the expected level of the interfering signal above threshold. The degradation effect of these signals has not been determined. The implementation of an L-band DME, which now appears probable, will remove this potential problem.

The separation-distance requirements for frequency assignment options 1 and 6 are the same for the majority of the interactions between MLS and radar equipments. One major exception is the case of height-finding radars wherein option 1 has some advantages over option 6.

APPENDIX A

FREQUENCY DISTANCE CURVES

This appendix contains F/D curves, Figures A-1 to A-13, generated for the following cases:

1. Adjacent band radars to MLS interactions.
2. MLS to adjacent band radars interactions.

The parameters in these curves is the coupling isolation (K) which covers a dynamic range of 100 dB to accommodate various likely situations such as changes in equipment power budgets, antenna gain levels, etc. In these curves, the frequency separation ranges from 1 MHz to 10,000 MHz.

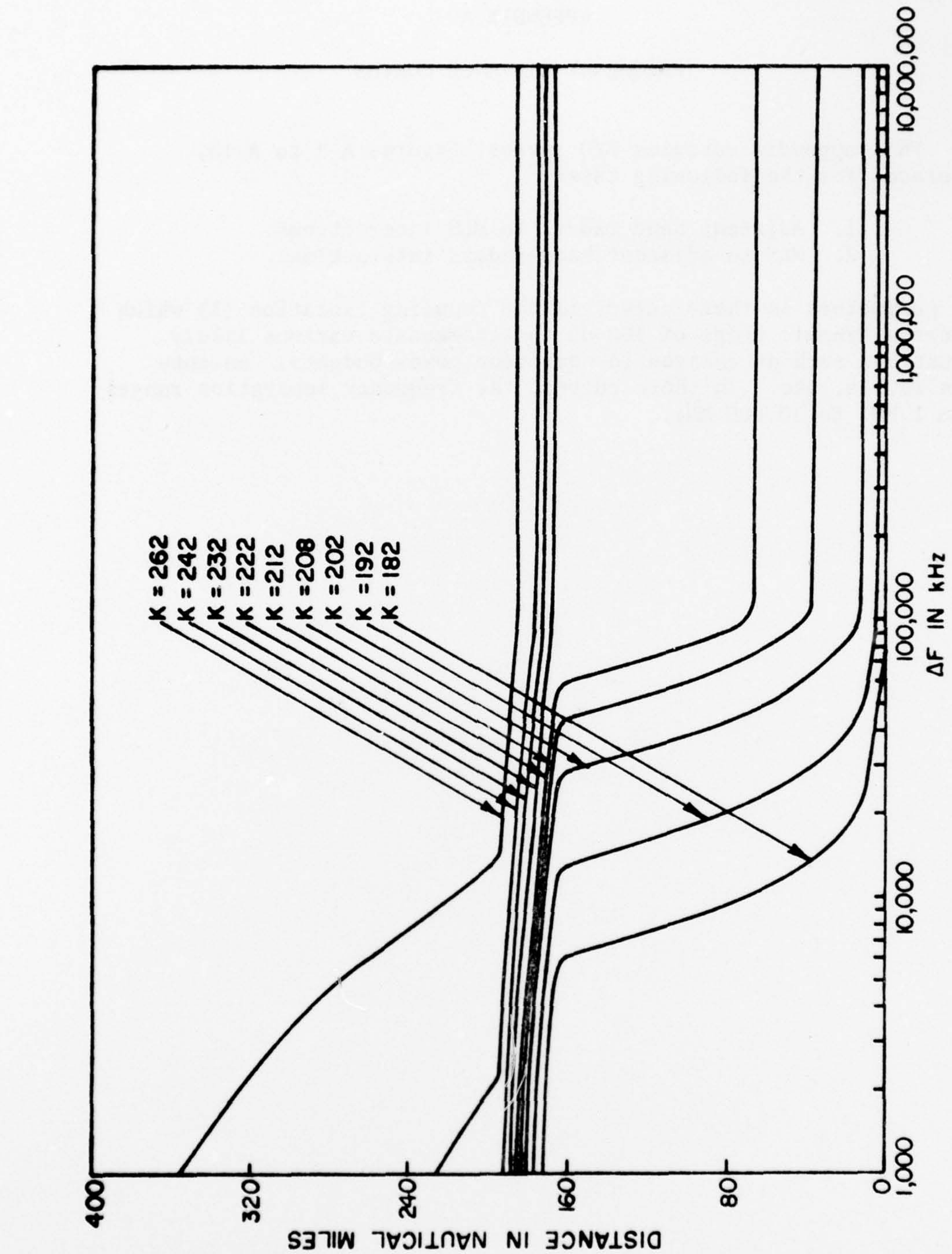

Figure A-1. Frequency distance curves: AN/TPS-40A transmitter to MLS angle receiver.

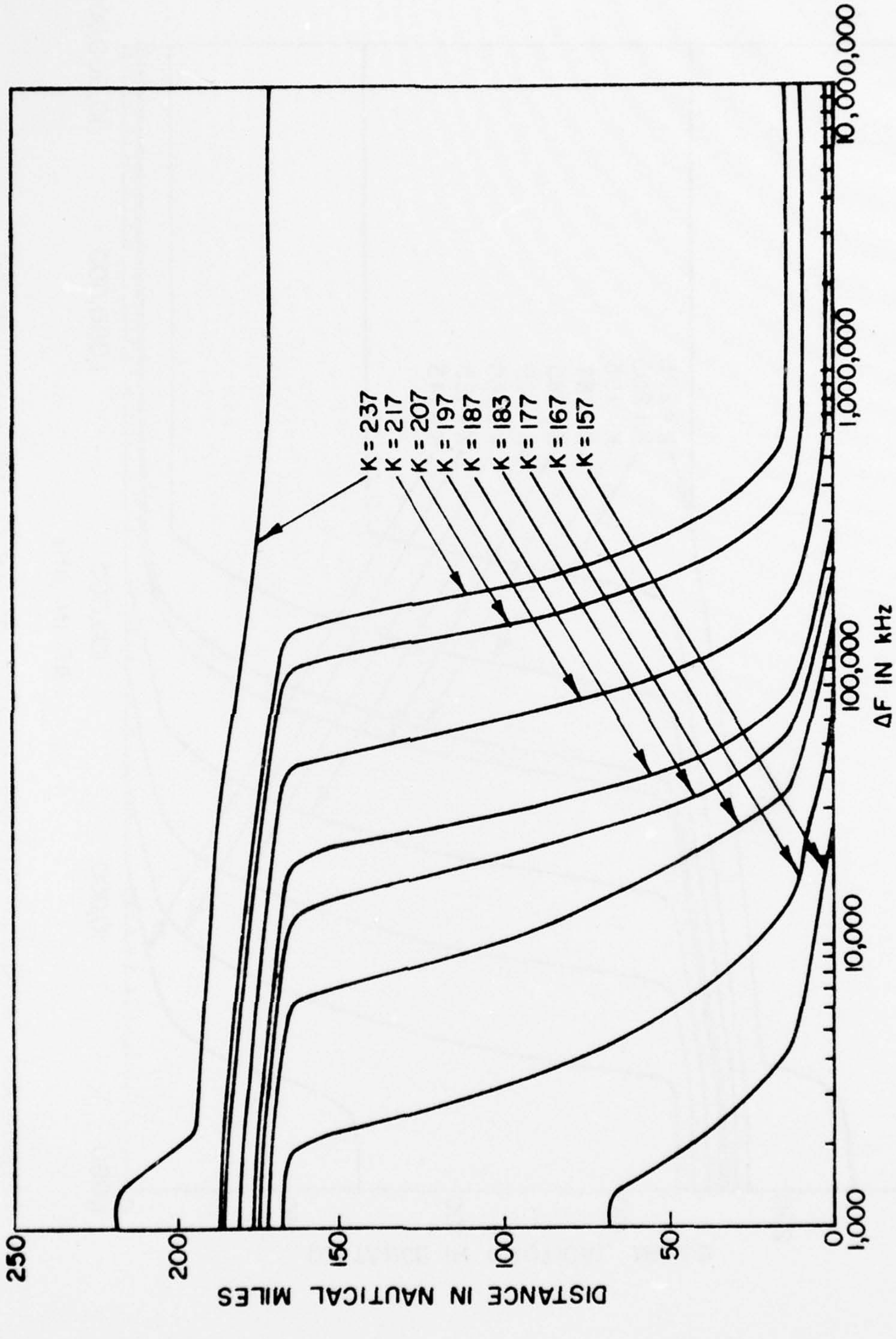

Figure A-2. Frequency distance curves: AN/SPS-10F transmitter to MLS angle receiver.

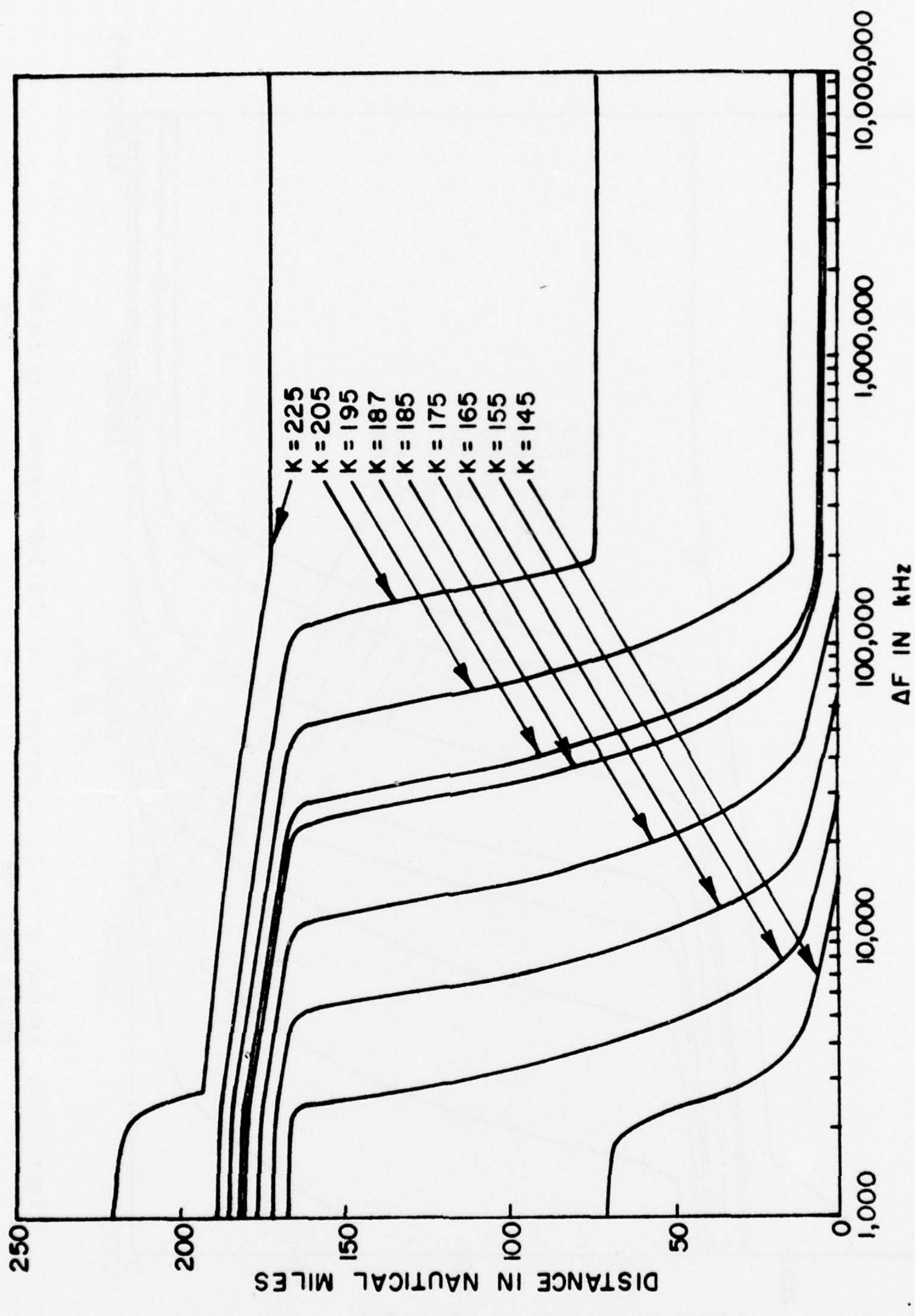

Figure A-3. Frequency distance curves: AN/FPS-77 transmitter to MLS DME receiver.

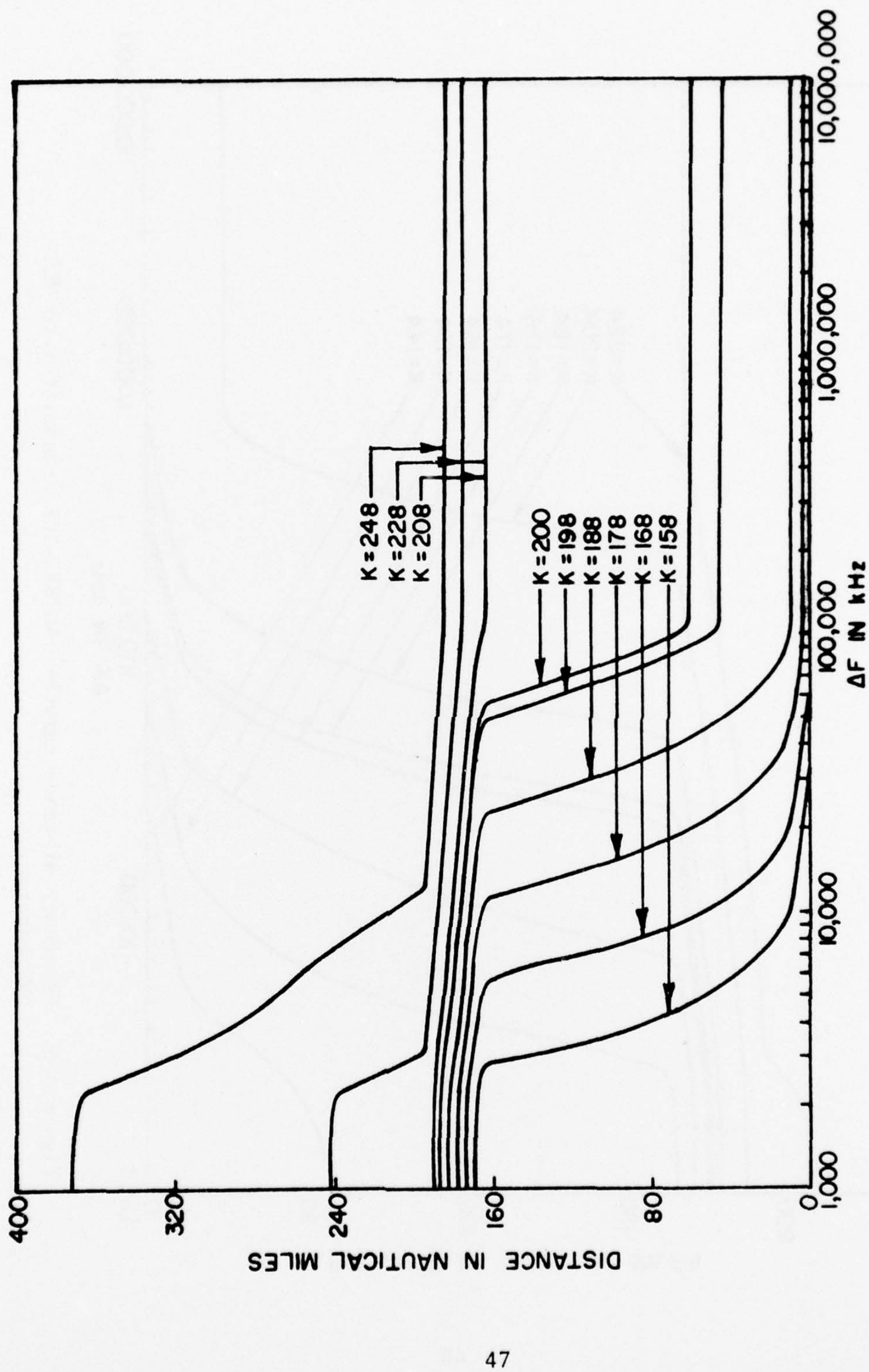

Figure A-4. Frequency distance curves: AN/TPS-40A transmitter to MLS DME receiver.

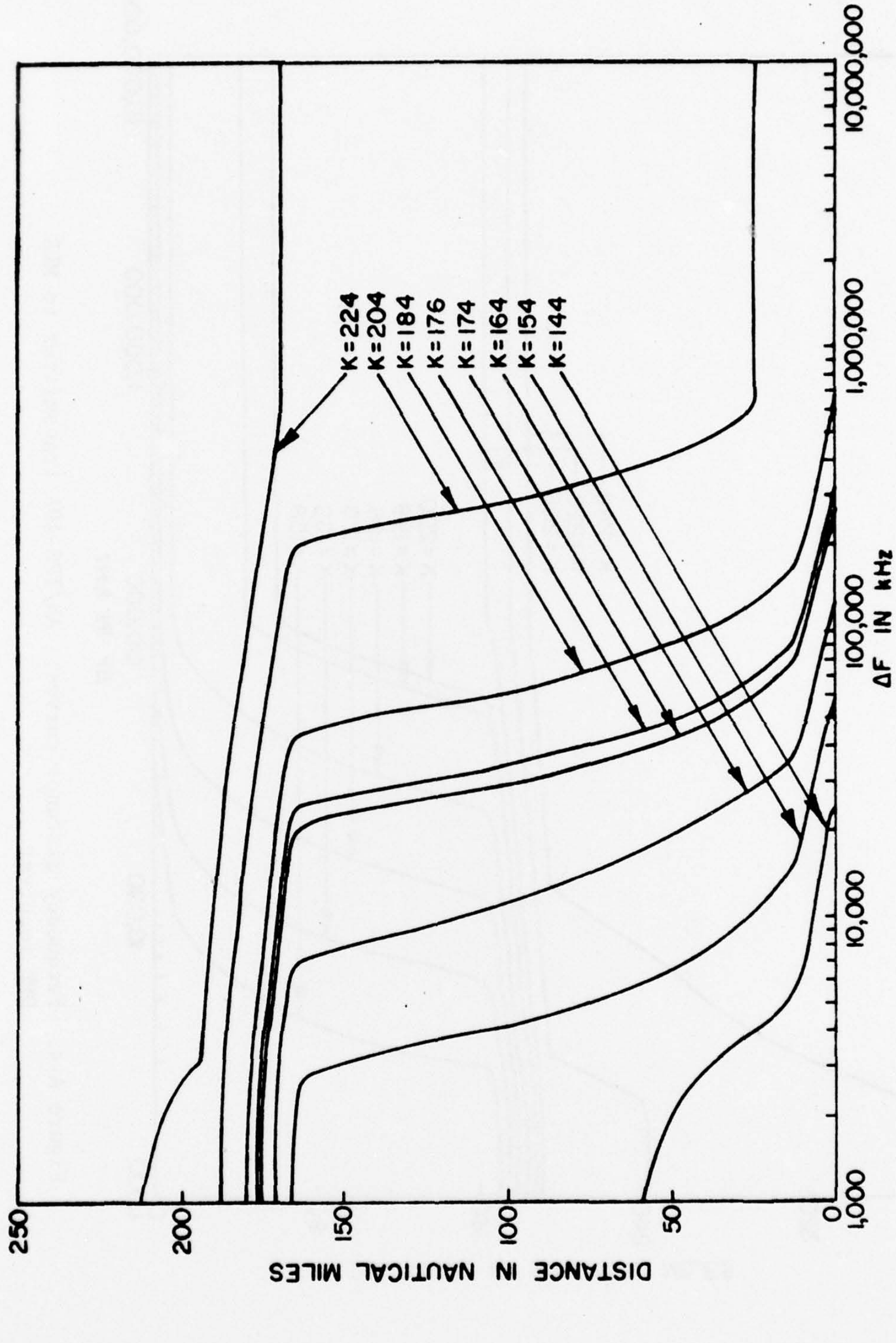

Figure A-5. Frequency distance curves: AN/SPS-10F transmitter to MLS DME receiver.

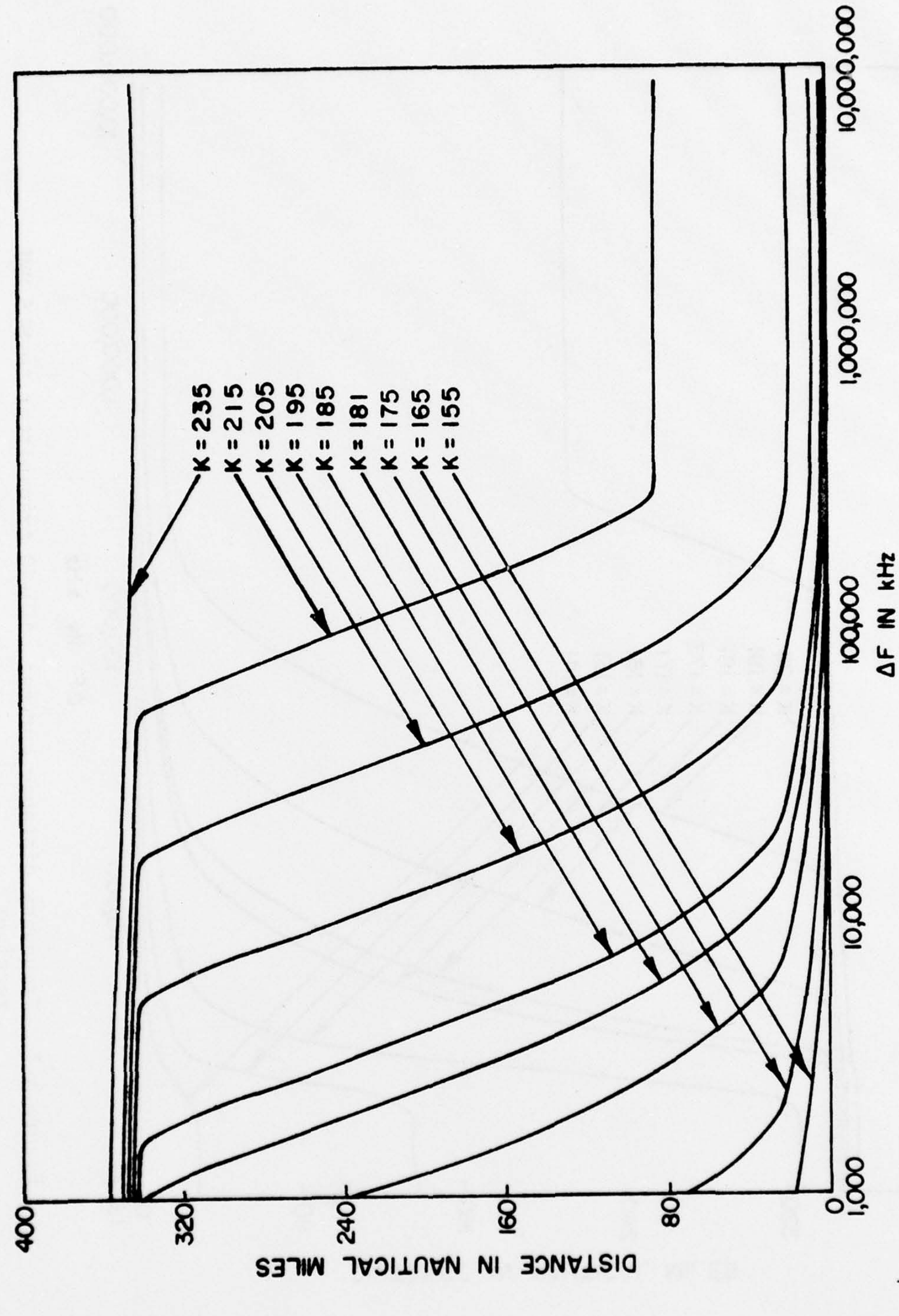

Figure A-6. Frequency distance curves: AVQ-10 transmitter to MLS angle receiver.

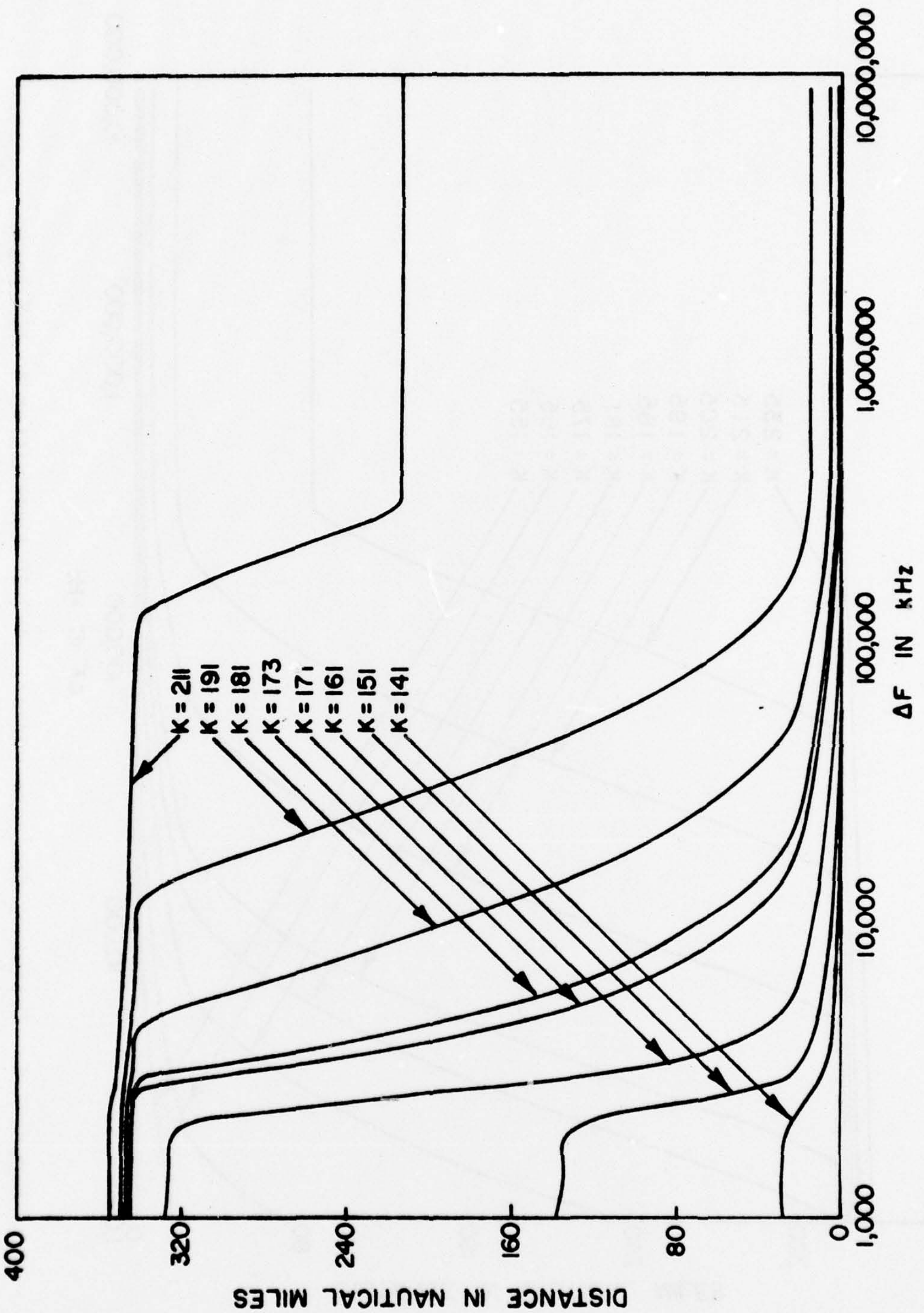

Figure A-7. Frequency distance curves: AVQ-10 transmitter to MLS DME receiver.

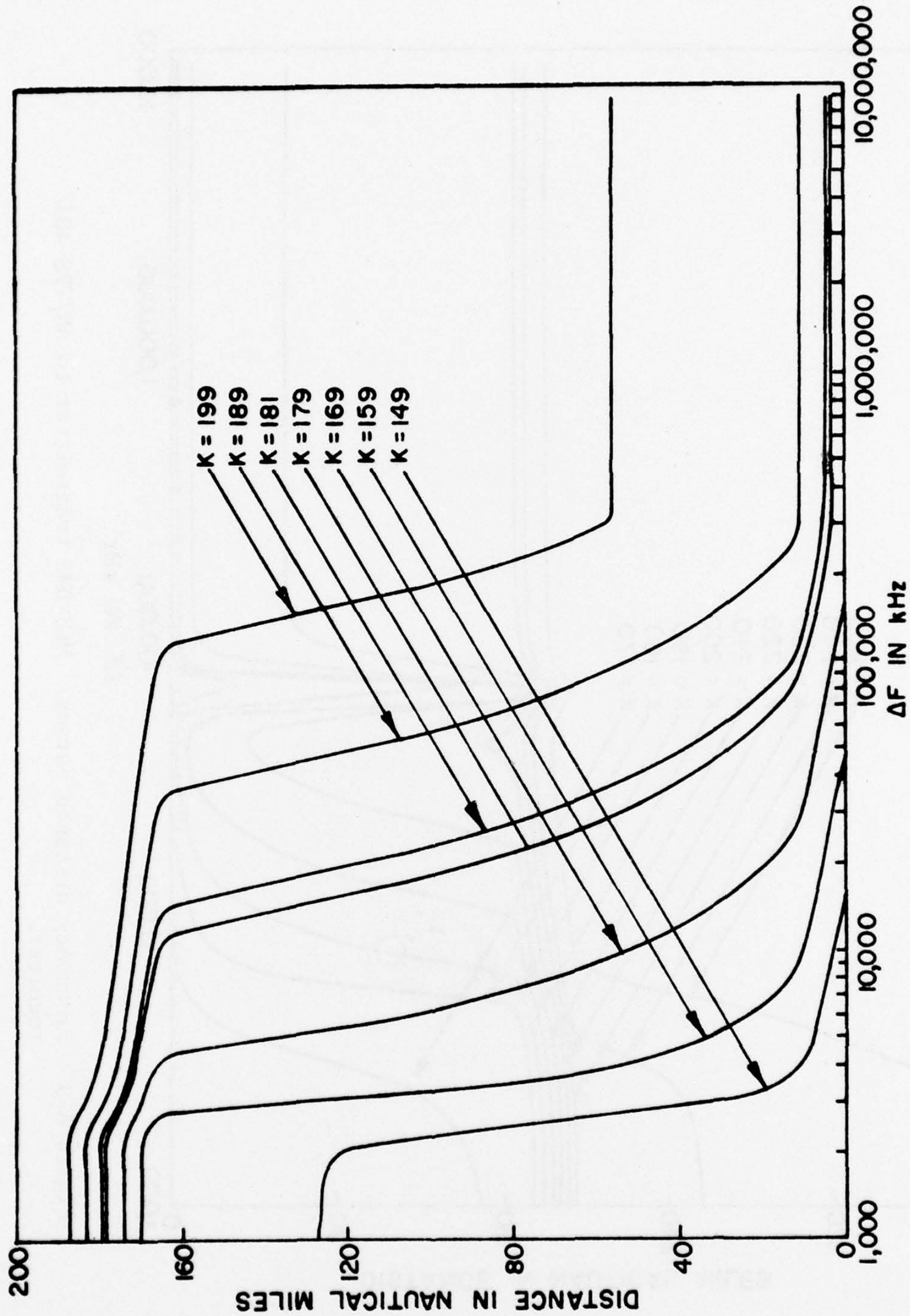

Figure A-8. Frequency distance curves: AVQ-10 transmitter to MLS DME receiver.

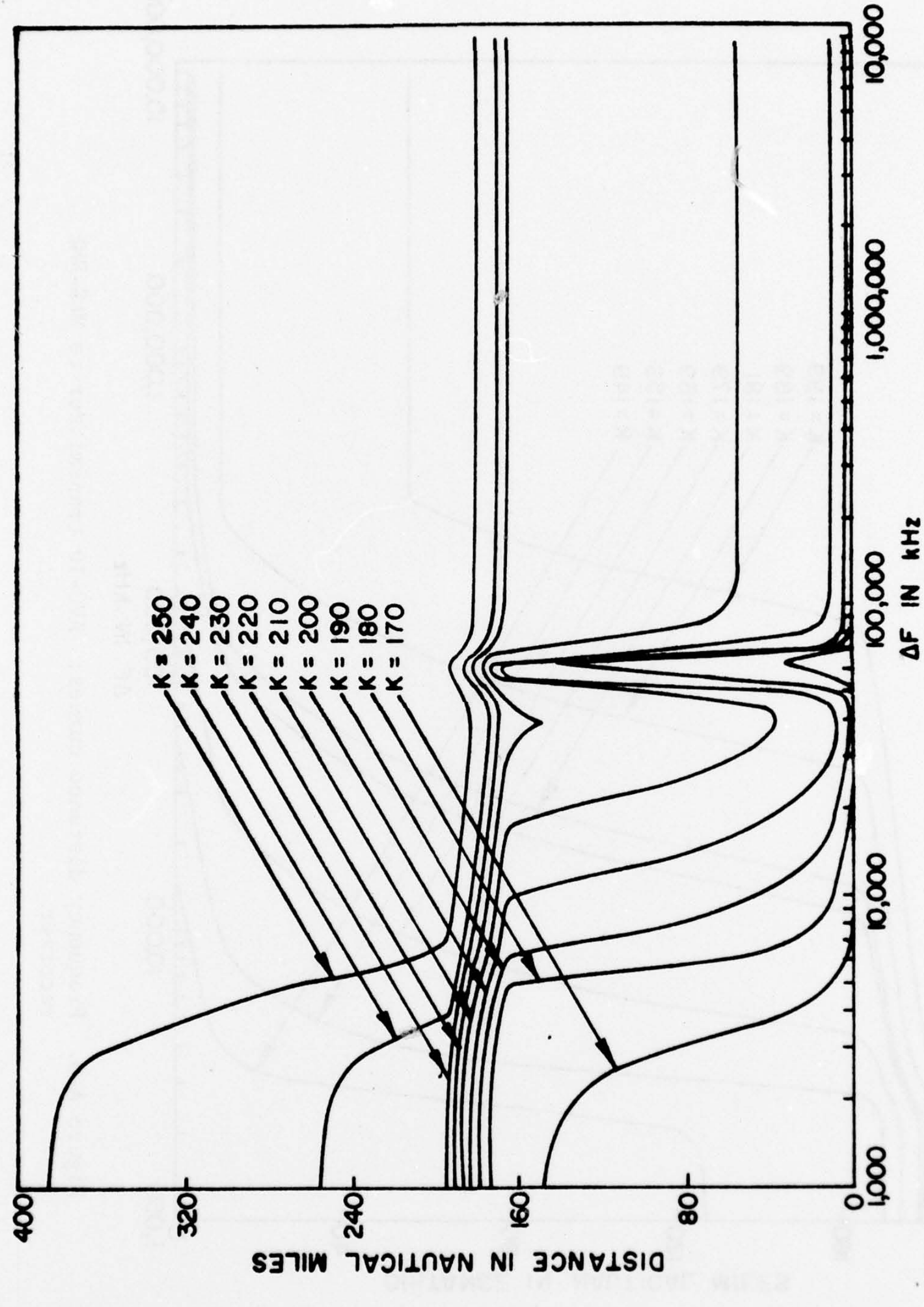

Figure A-9. Frequency distance curves: MLS DME transmitter to AN/TPS-40A receiver.

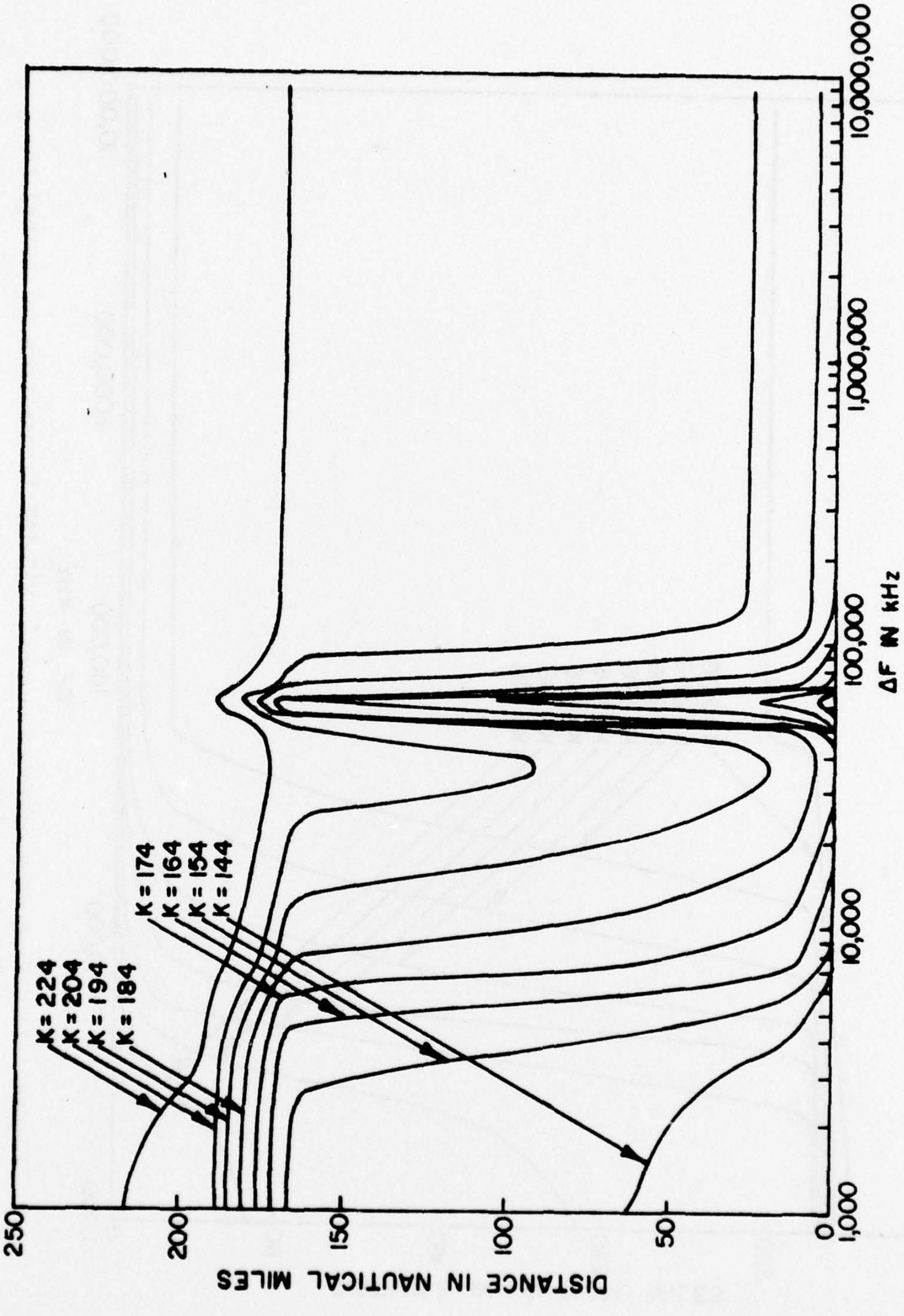

Figure A-10. Frequency distance curves: MLS DME transmitter to AN/SPS-10F receiver.

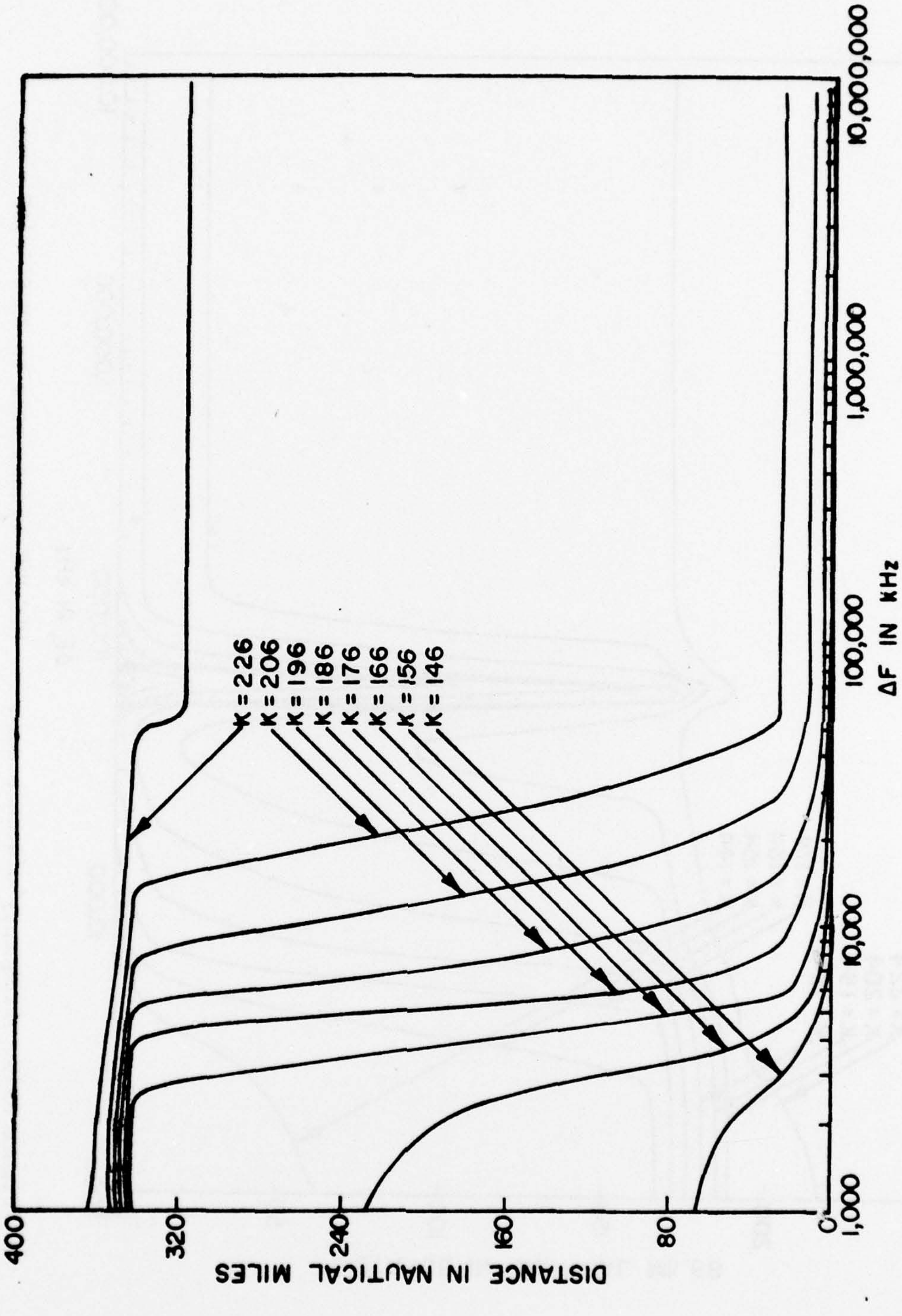

Figure A-11. Frequency distance curves: MLS DME transmitter (airborne) to AVQ-10 receiver.

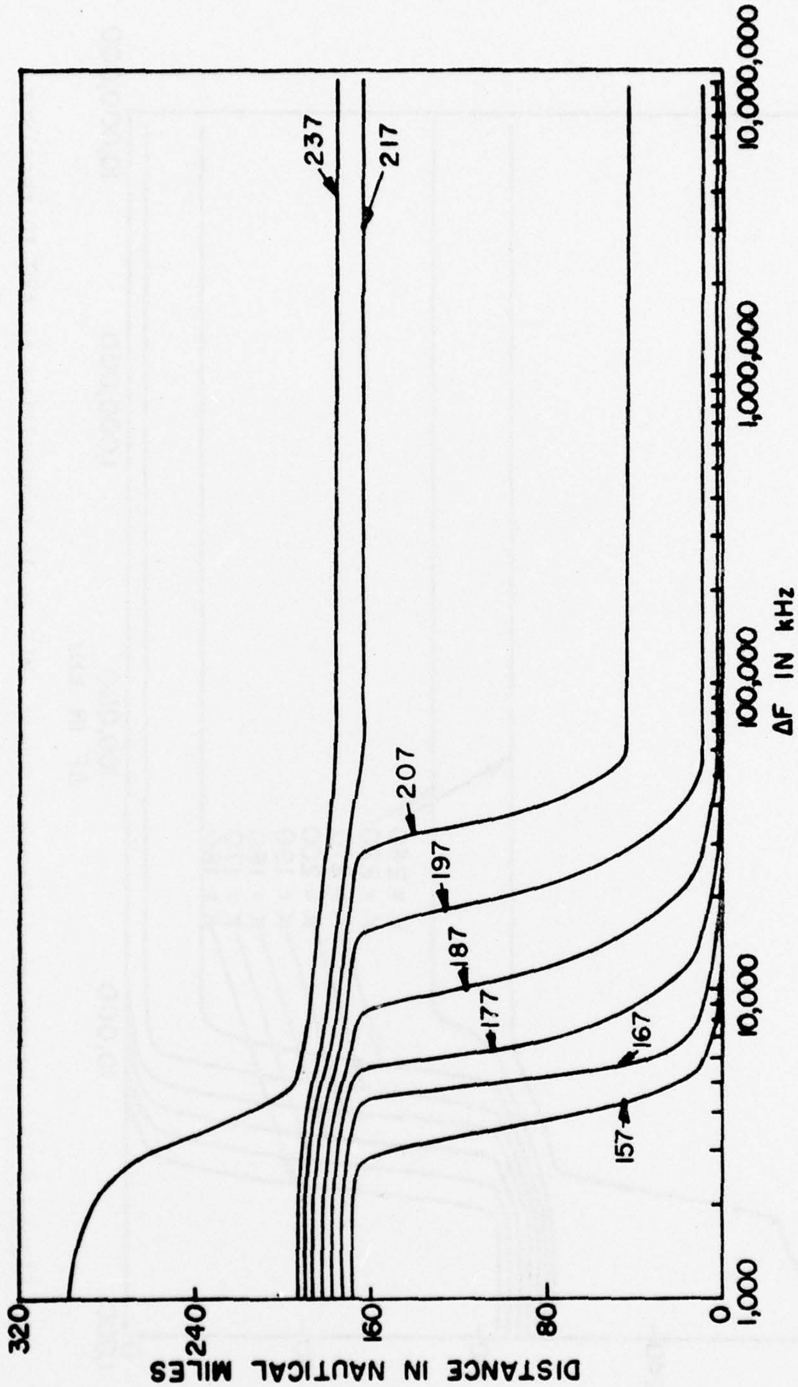

Figure A-12. Frequency distance curves: MLS DME transmitter (ground) to AVQ-10 receiver.

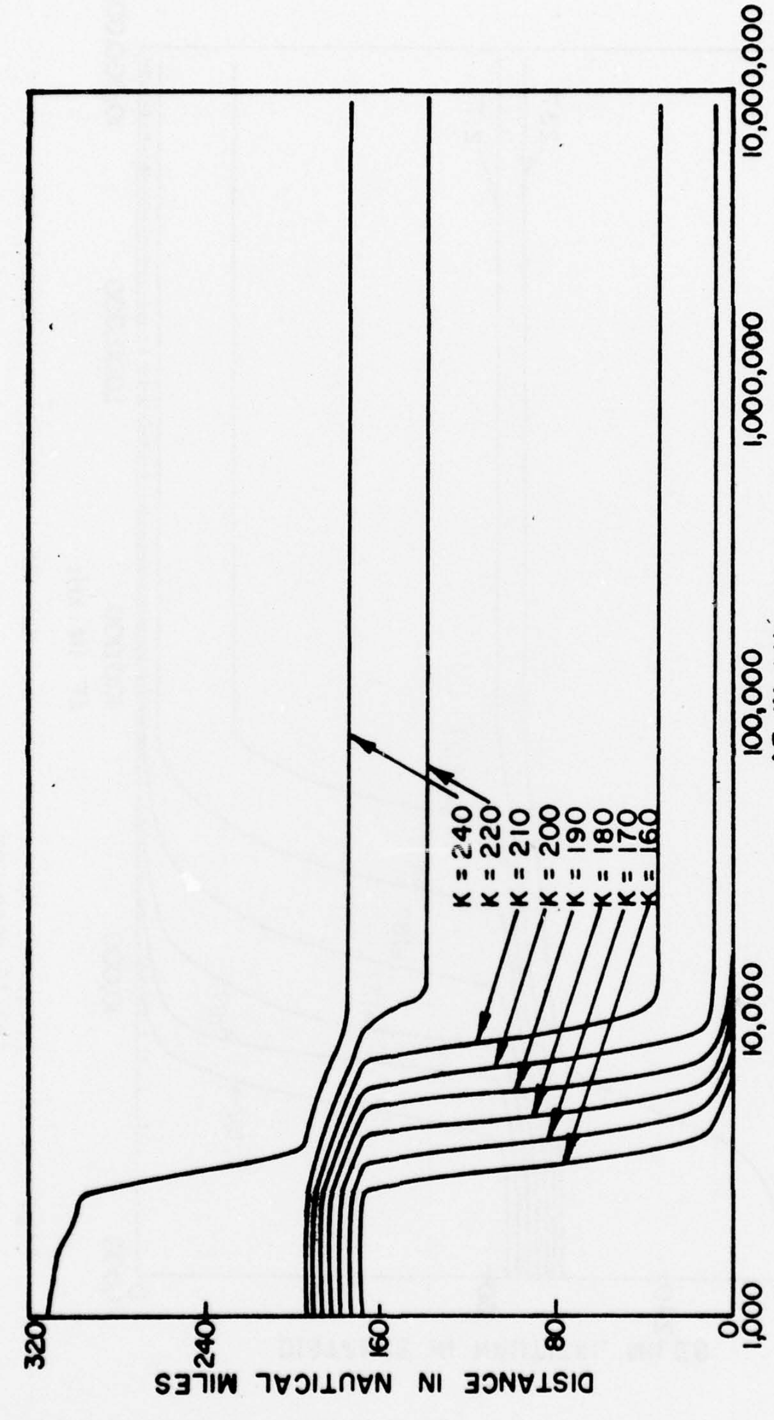

Figure A-13. Frequency distance curves: MLS angle transmitter to AVQ-10 receiver.